STUDY SCALING RELATION AND THEIR SCATTER

TWO CASES OF EXTREME MERGERS

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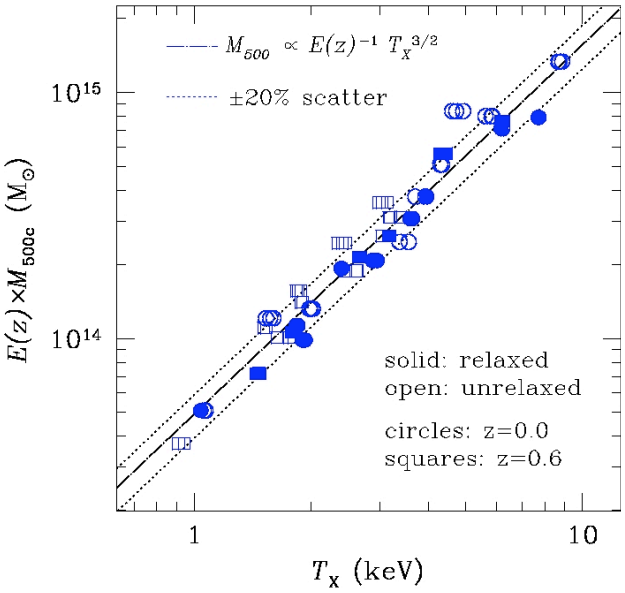
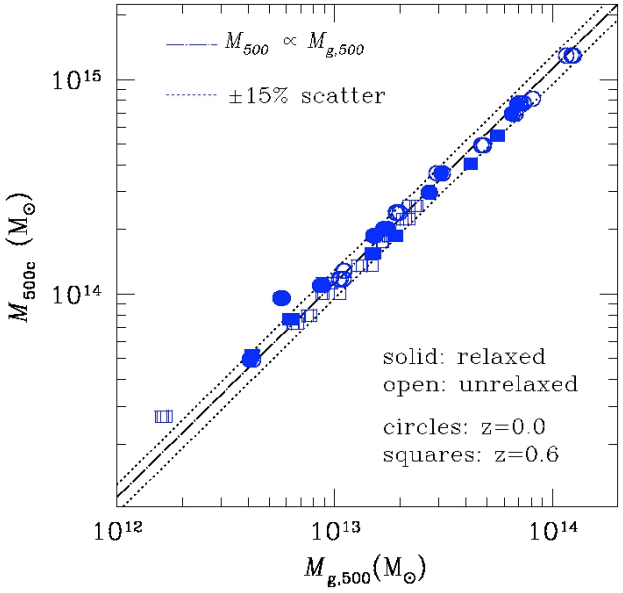
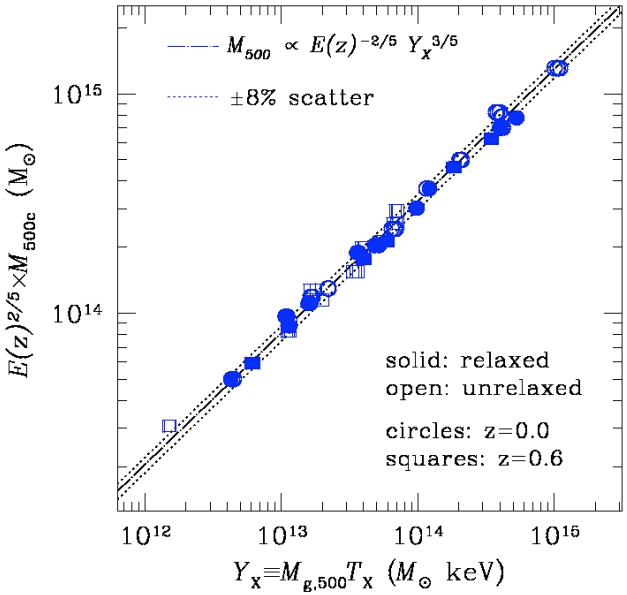
May 7-9, 2008 NY, Columbia University

SCALING RELATIONS







by Kravtsov et al 06

M_{tot} =

$10^{14.41}\ (T_X/3\ \mathrm{keV})^{1.521}$

$10^{14.35}\ (M_{gas}/2\ 10^{13})^{0.921}$

$10^{14.27}\ (Y_X/4\ 10^{13})^{0.581}$

$Y_X = M_{gas}\ T_X$

all clusters

$[7 10^{13} 2 10^{15}] M_{sun}/h$

all z (=0,0.6)

All quantities at R_{500}

excluding 0.15 R_{500}

May 7-9, 2008

SIMULATIONS

- Physics: radiative cooling,uniform time-dependent UV background, star formation from multi-phase interstellar medium, galactic winds powered by SN

ONE SPECIAL CLUSTER

Mass resolution: DM particle = 1.74 10^8 M_{sun}/h GAS particle =2.6 10^7 M_{sun}/h; Physical resolution: softening 2.5 kpc/h;Total mass at R_{200}: M_{200}= 2 10^{15} M_{sun}/h

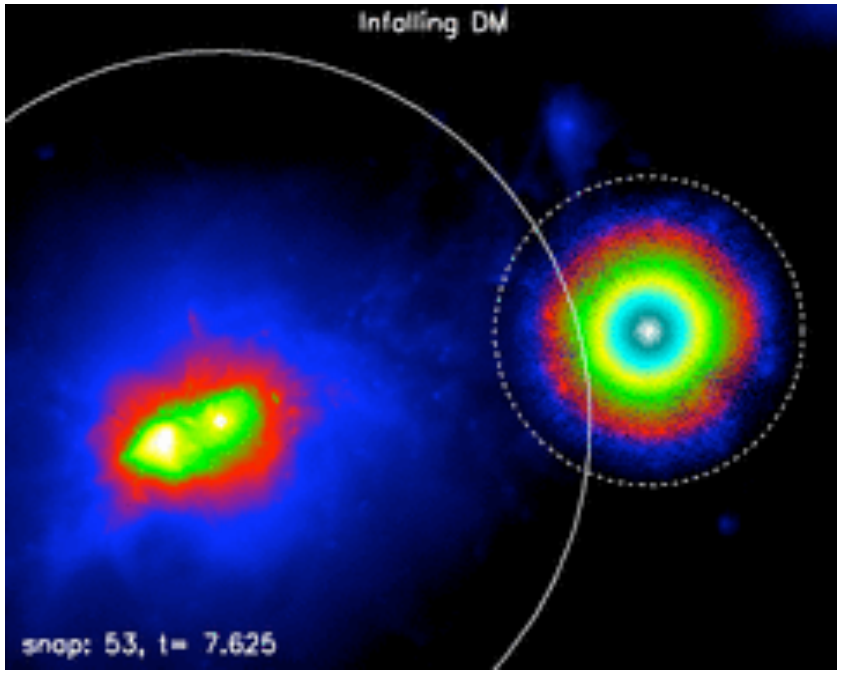
Active dynamic history and strong merging (Mach number 2.5),merging mass ratio 1:10

ONE STRONG MERGER

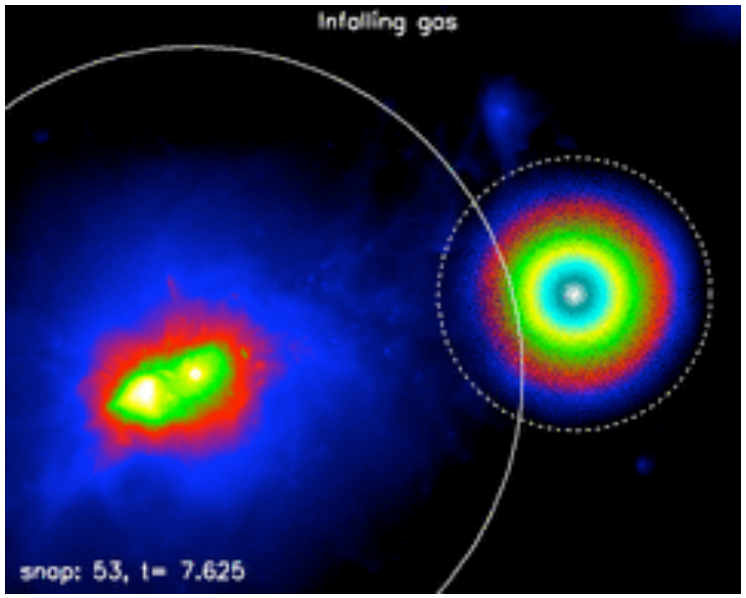
1 million particles inside R_{200}, merging mass ratio 1:1

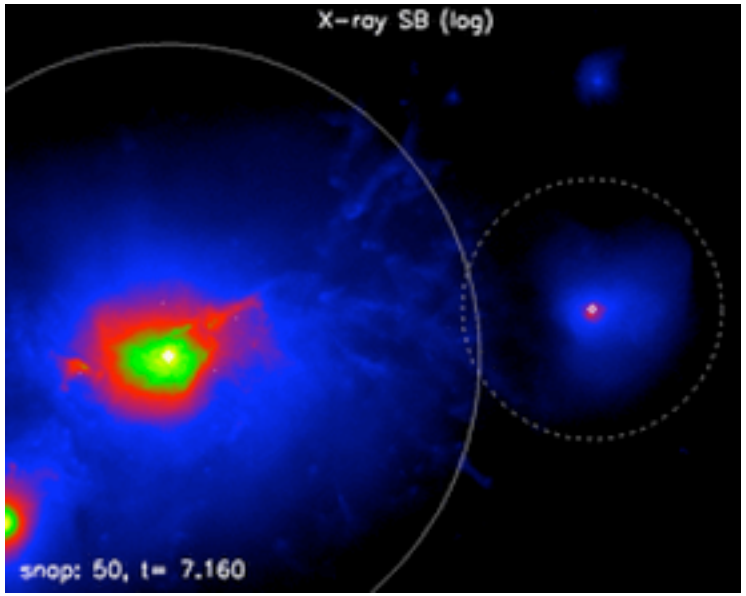
THE SPECIAL CASE (BULLET-LIKE)

DM



GAS





By Klaus Dolag

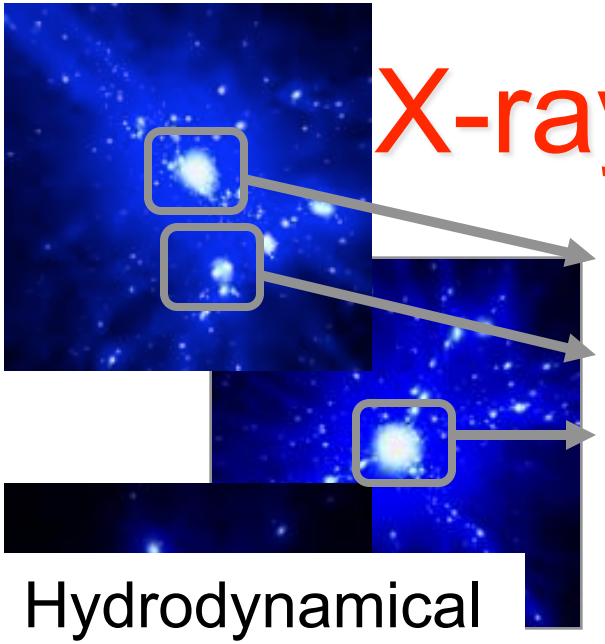
galaxies

May 7-9, 2008

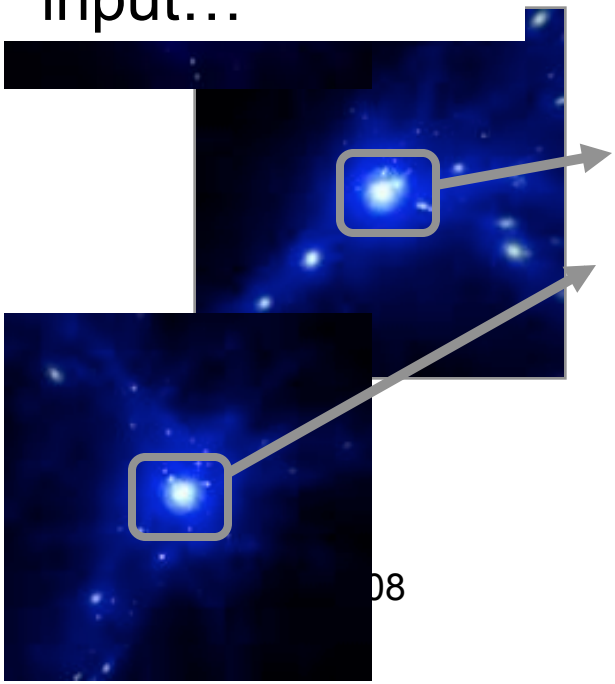
NY, Columbia University

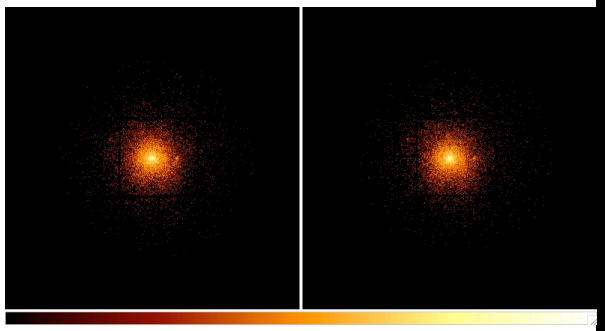
X-ray Map Simulator

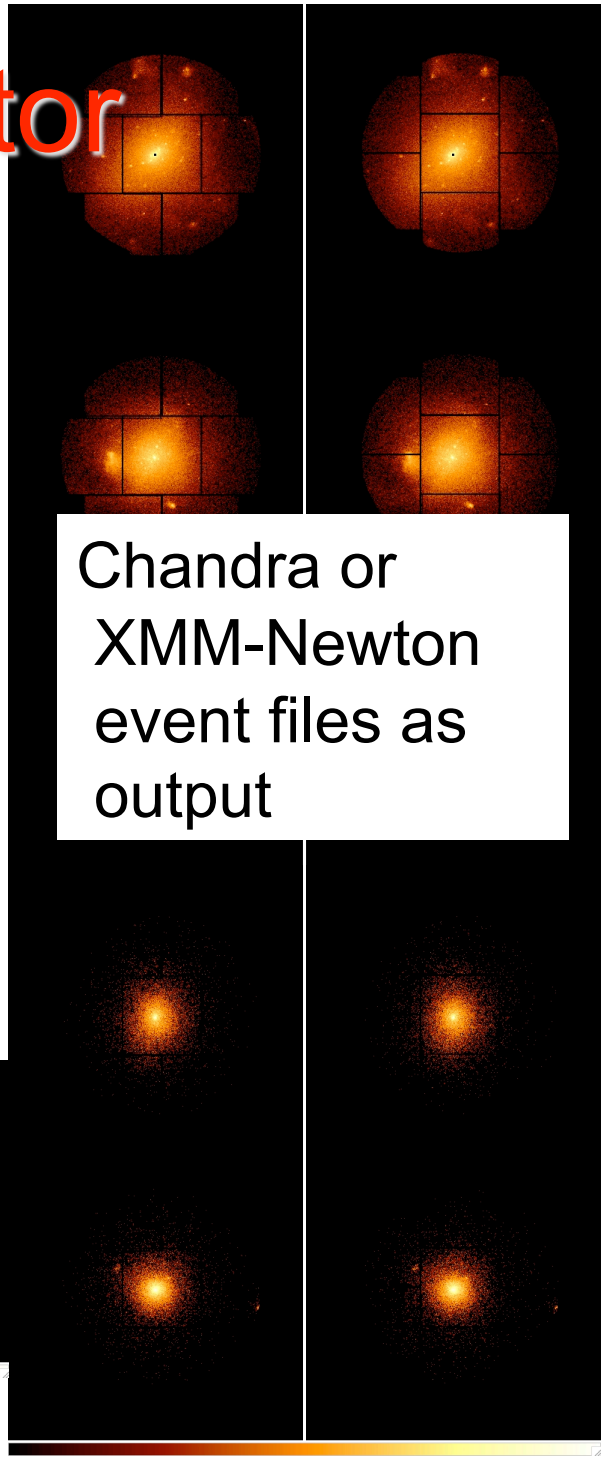
Rasia et al. 07 Gardini et al. 04



Hydrodynamical simulations as input…

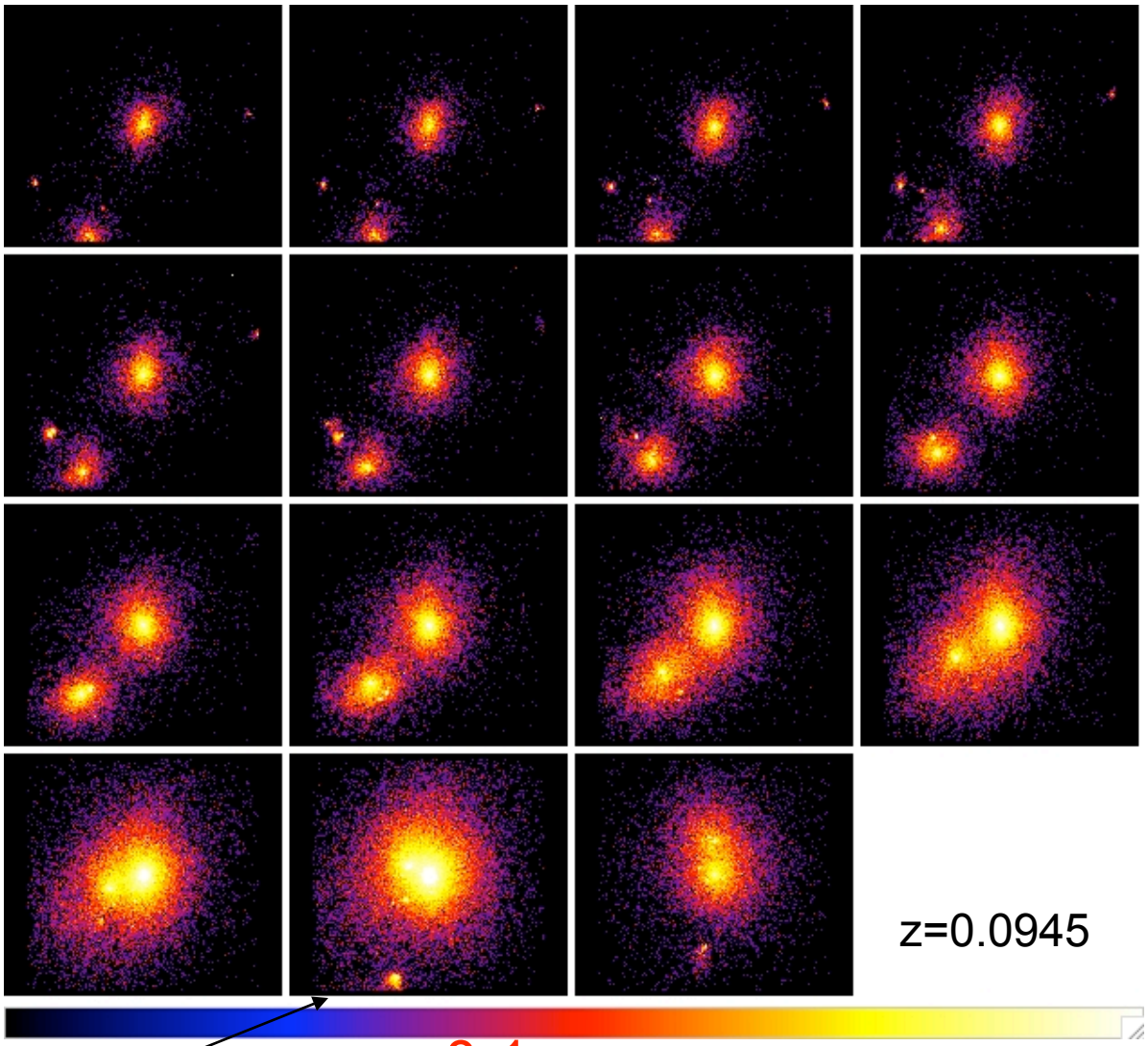






Chandra or XMM-Newton event files as output

THE 1:1 MERGER CASE



Time denoted by a star in the plots

NY, Columbia University

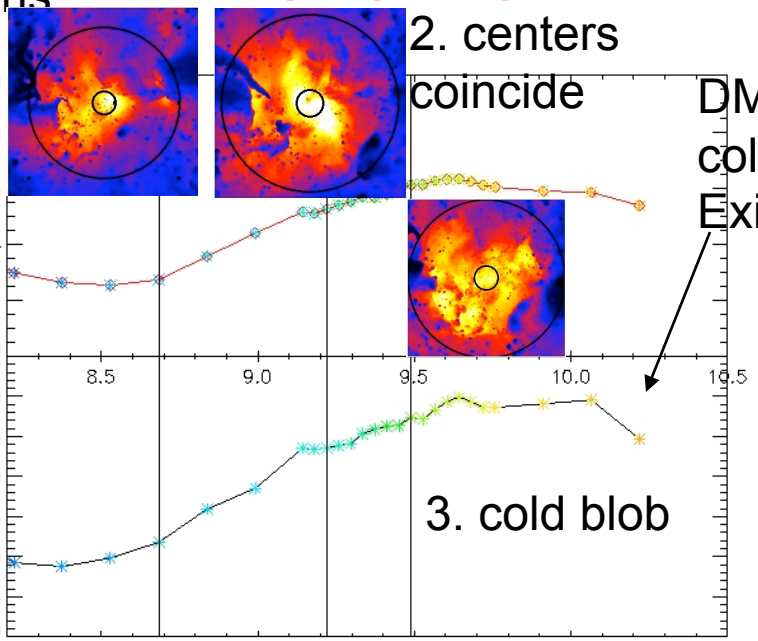
SCALING RELATION

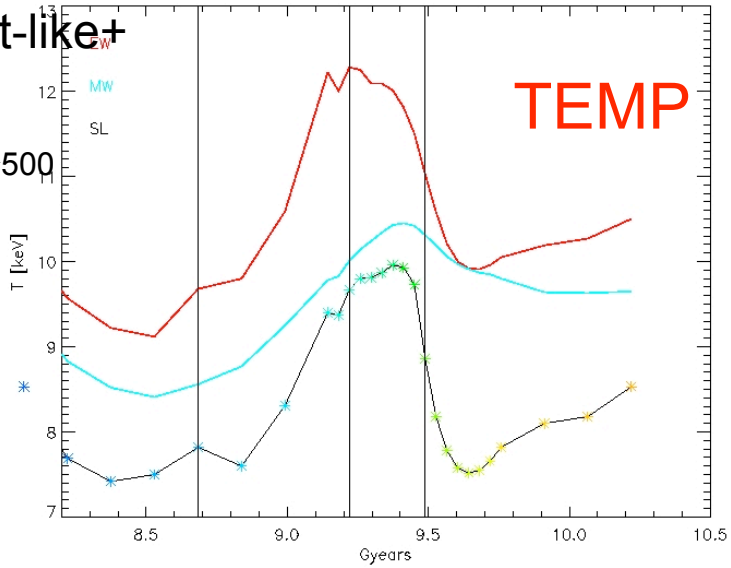
- SIMULATION
- All the quantities (T_{sl}, M_{gas}, $Y_X=T_{sl}$ M_{gas})computed inside R_{500} (excluding 0.15 R_{500}) with R_{500} determined from the simulation itself

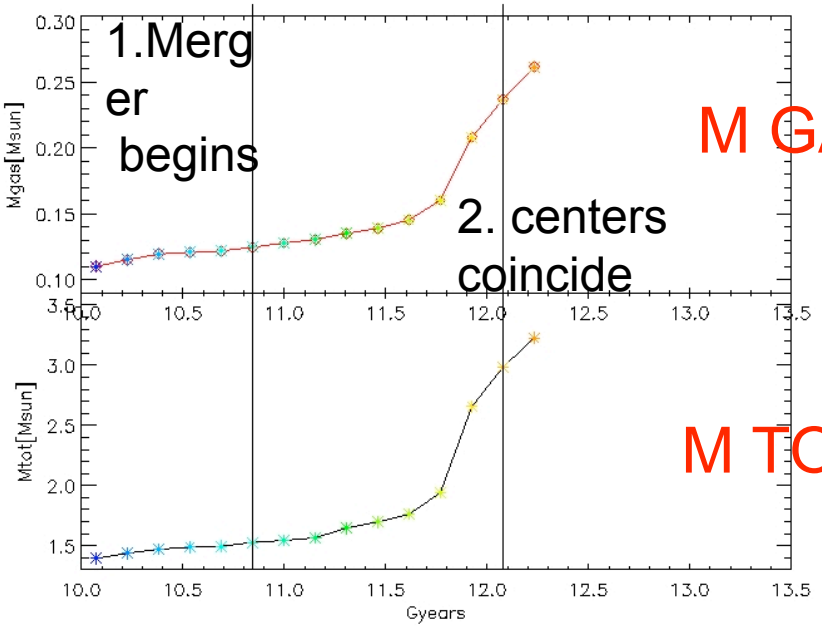
- OBSERVATION
- Cluster processed through XMAS2 to obtained X-ray images
- Mask blobs
- All the quantities from X-ray measurements computed in R_{500} (excluding the core) estimated from X-ray.

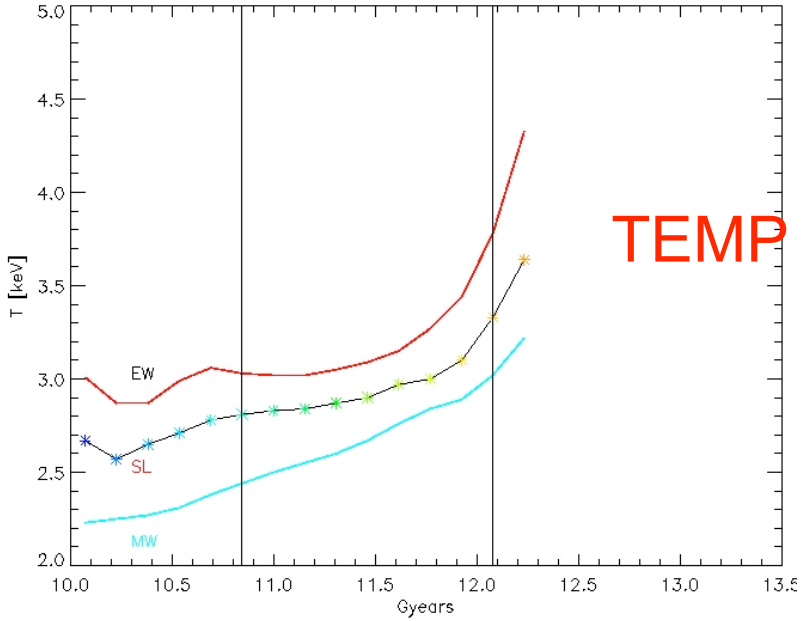
Evolution intrinsic properties

1.Merger begins









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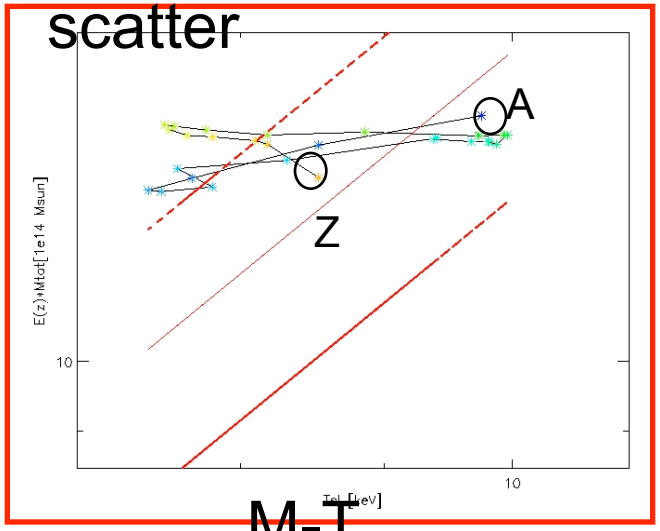
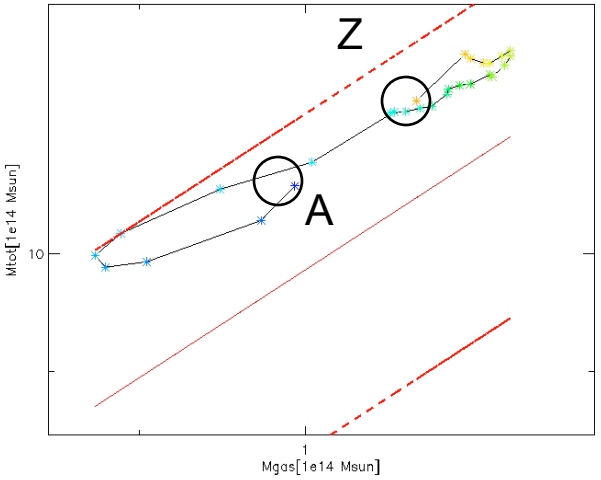
SCALING RELATION FROM SIMULATIONS

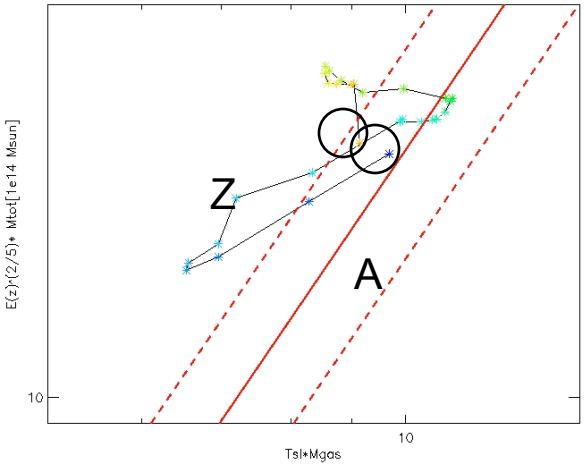
Red lines are the relations proposed by Kravtsov et al 06 + their scatter



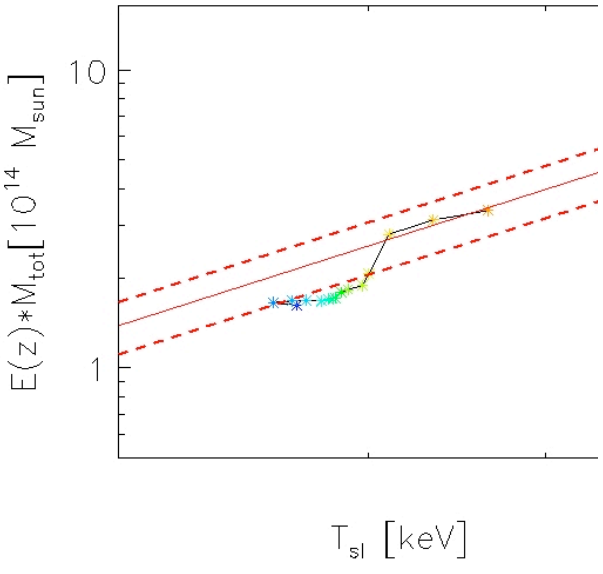
$M\text{-}T_{sl}$

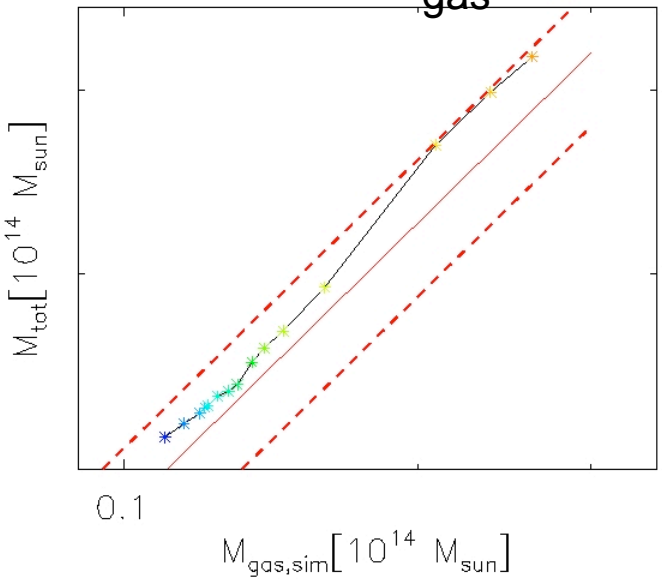


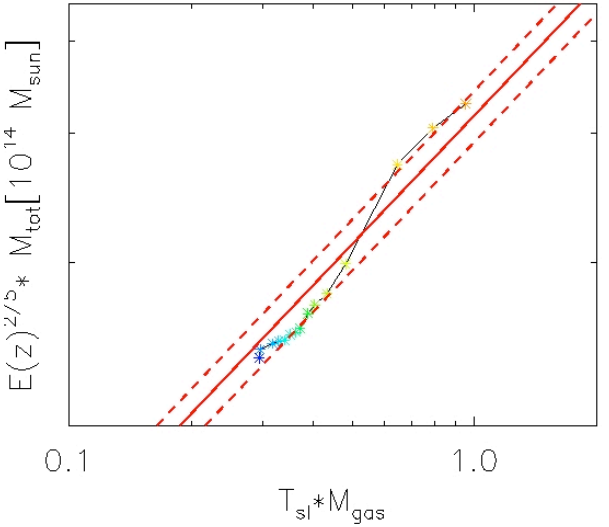
$M\text{-}M_{gas}$



$M\text{-}Y_{x}$







Scatter 20 %, 15%, 8%

SCALING RELATION

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TEMPERATURE

- Mask blobs
- Spectra: [0.5 7] keV, fitting with one single-temperature mekal model (free parameters: T, Z and K)
- First measure at R_{500} computed directly from simulation

S-B AND GAS DENSITY

- Surface brightness profile: [0.5 2] keV images
- Gas density fitting formulae:

$$n^2\{(r/rc)^a[1+(r/r_{c1})^2]^{(a/2-3b1)}[1+(r/rs)^g]^{e/g}\} + m^2\{[1+(r/r_{c2})^2\ ]^{3b2/2}\ \}$$

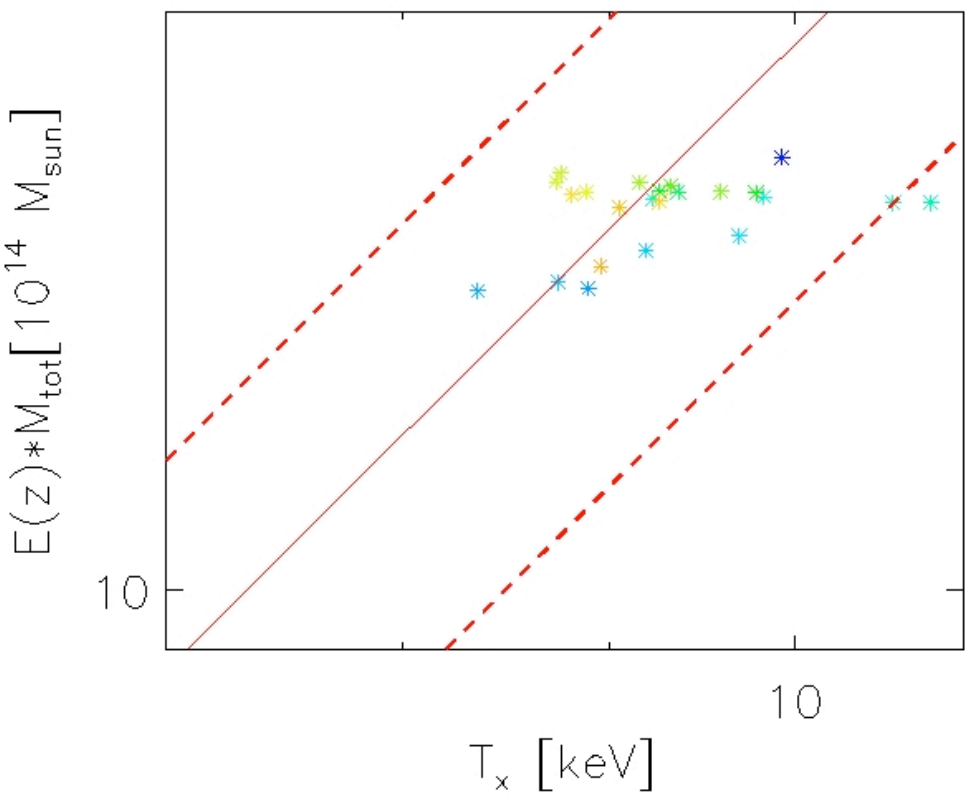
(Vikhlinin et al. 05)

- With the gas mass profile we calculate R_{500} as the radius that satisfy at

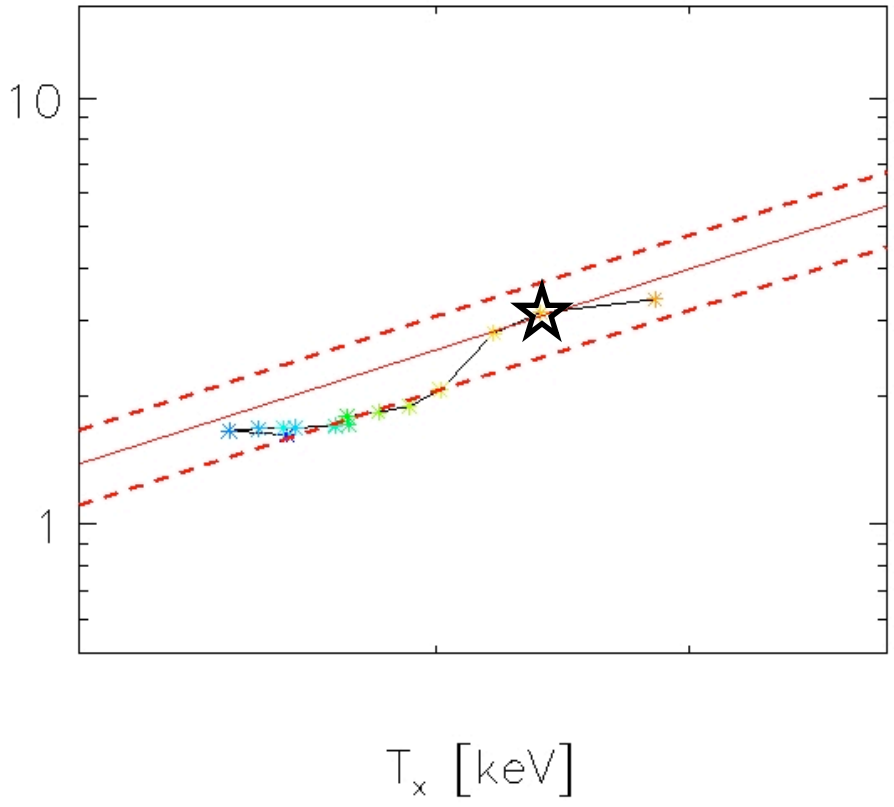
$4\ \pi/3\ 500\ \rho_c(z)\ r^3_{500} = 10^{14.27}\ E(z)^{\ 2/5}\ [Y_X(R_{500})]^{0.581}$
(Kravtsov et al. 06)

MASS - TEMPERATURE

Bullet-like



1:1

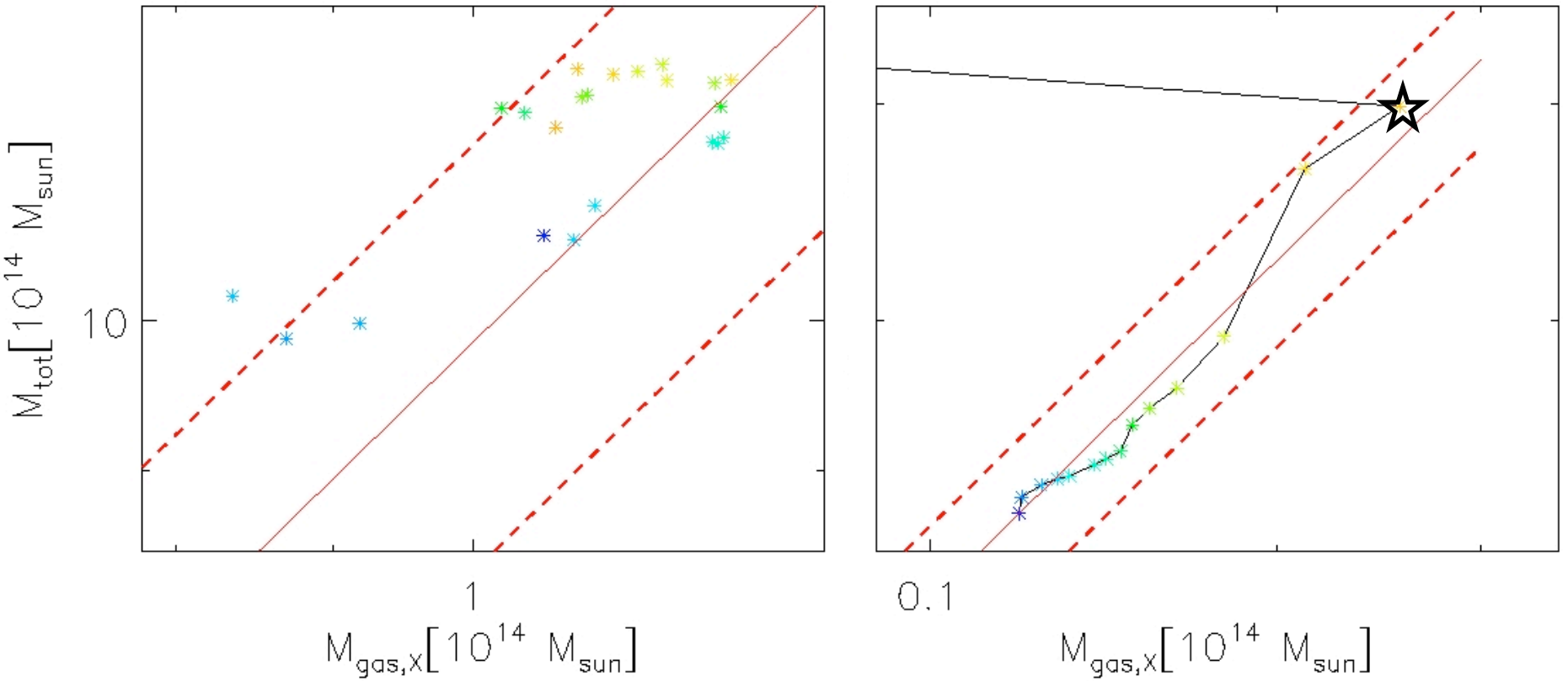


The overall behavior of the bullet-like M-T is changed substantially. Points are closer to the relation by Kravtsov et al. and within 10% of scatter

MASS - GAS MASS

Bullet-like

1:1

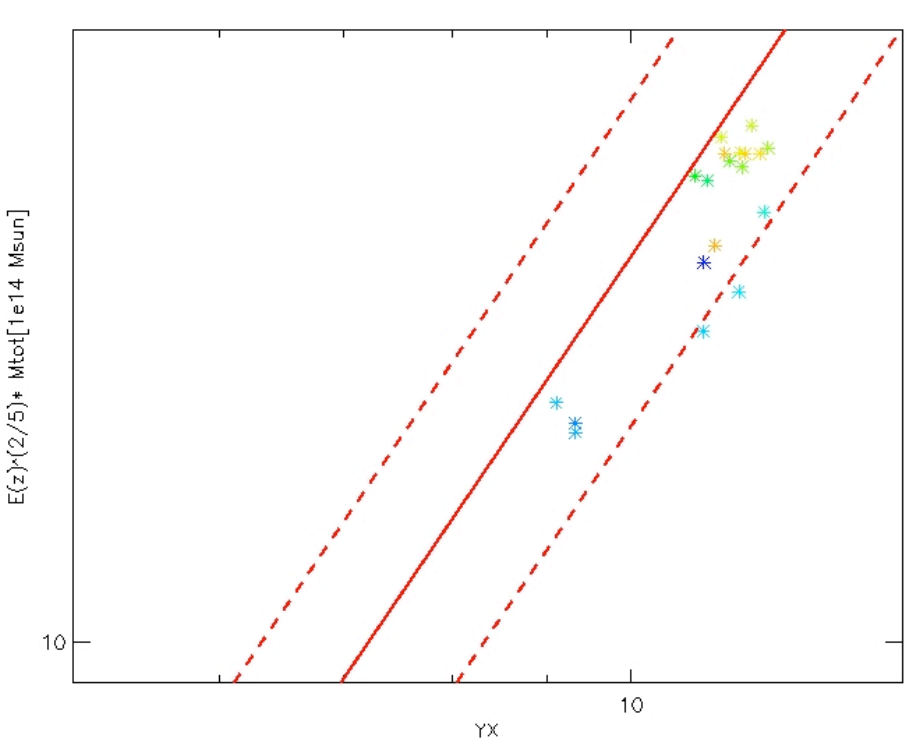


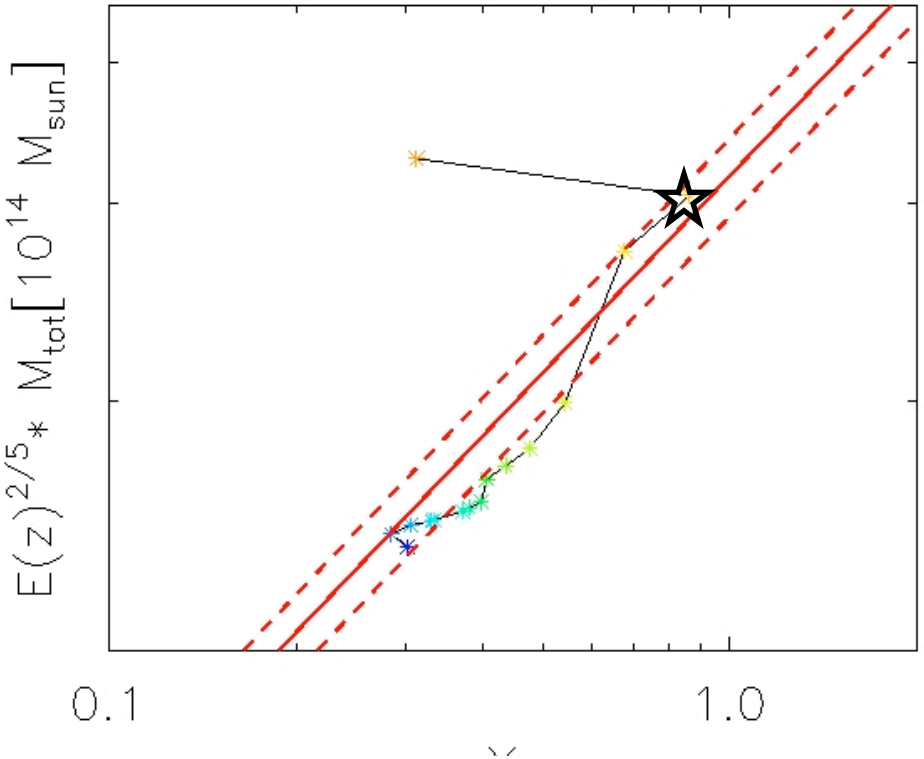
There is a larger spread in the gas mass computed with the X-ray technique, at the same time more points approach to the best-fit by Kravtsov

MASS - YX PARAMETER

Bullet-like

1:1

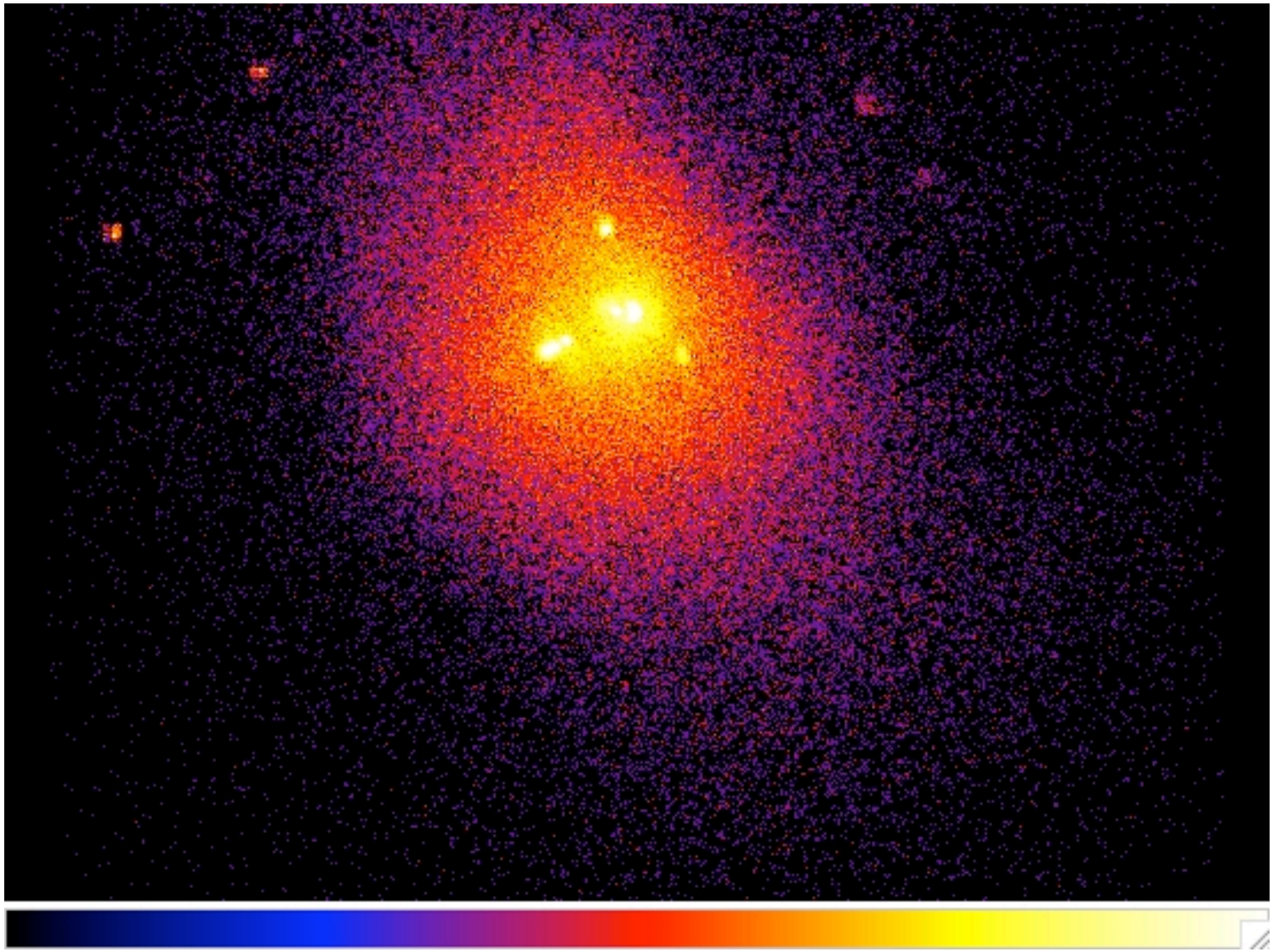




The observed Yx parameter is in agreement with Kravtsov relation.

The “observed scatter” is substantially reduced

CONLUSION 1: We test the robustness of the scaling relation and we find that they are satisfied also in the case of a strong merger



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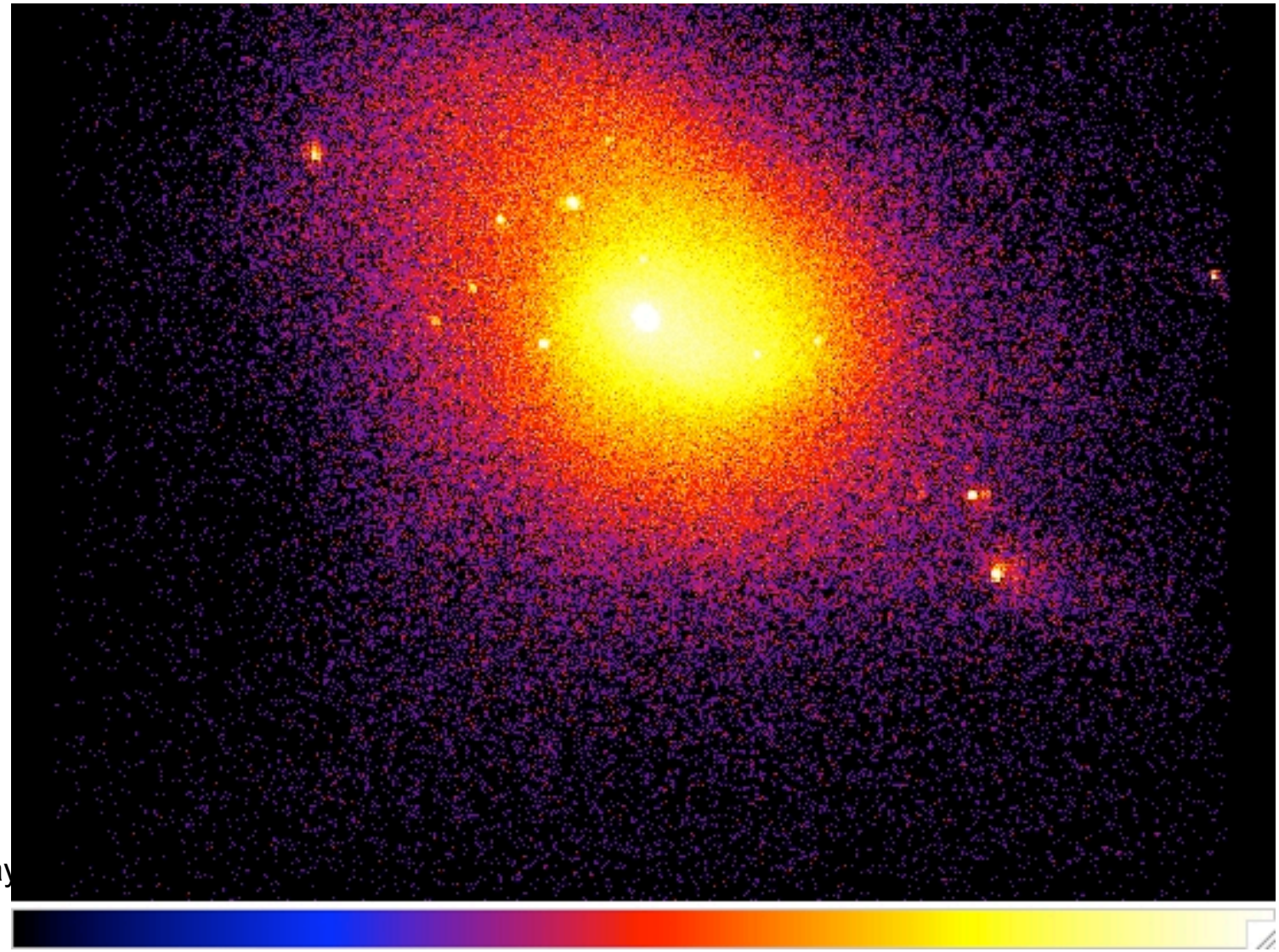

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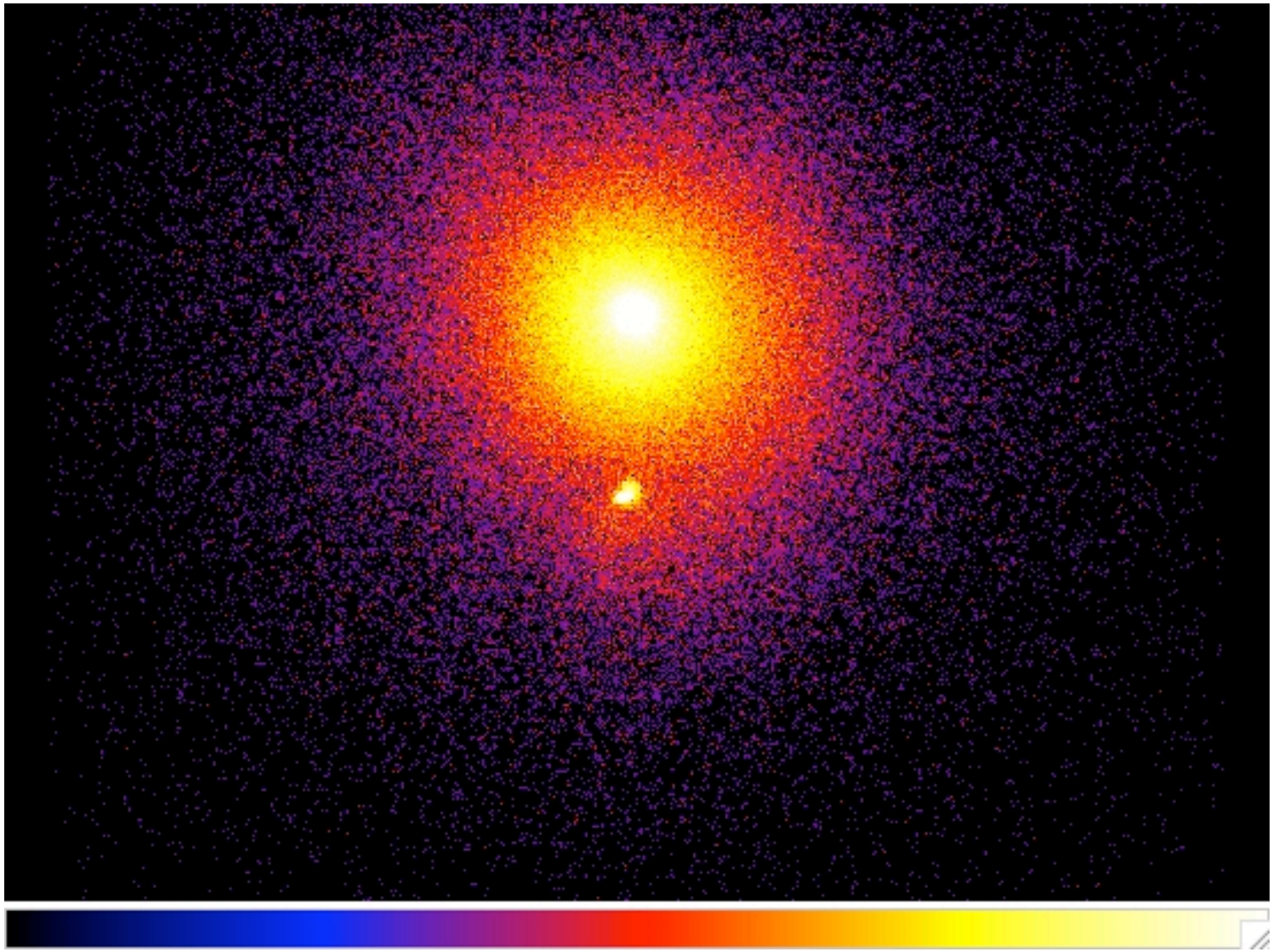

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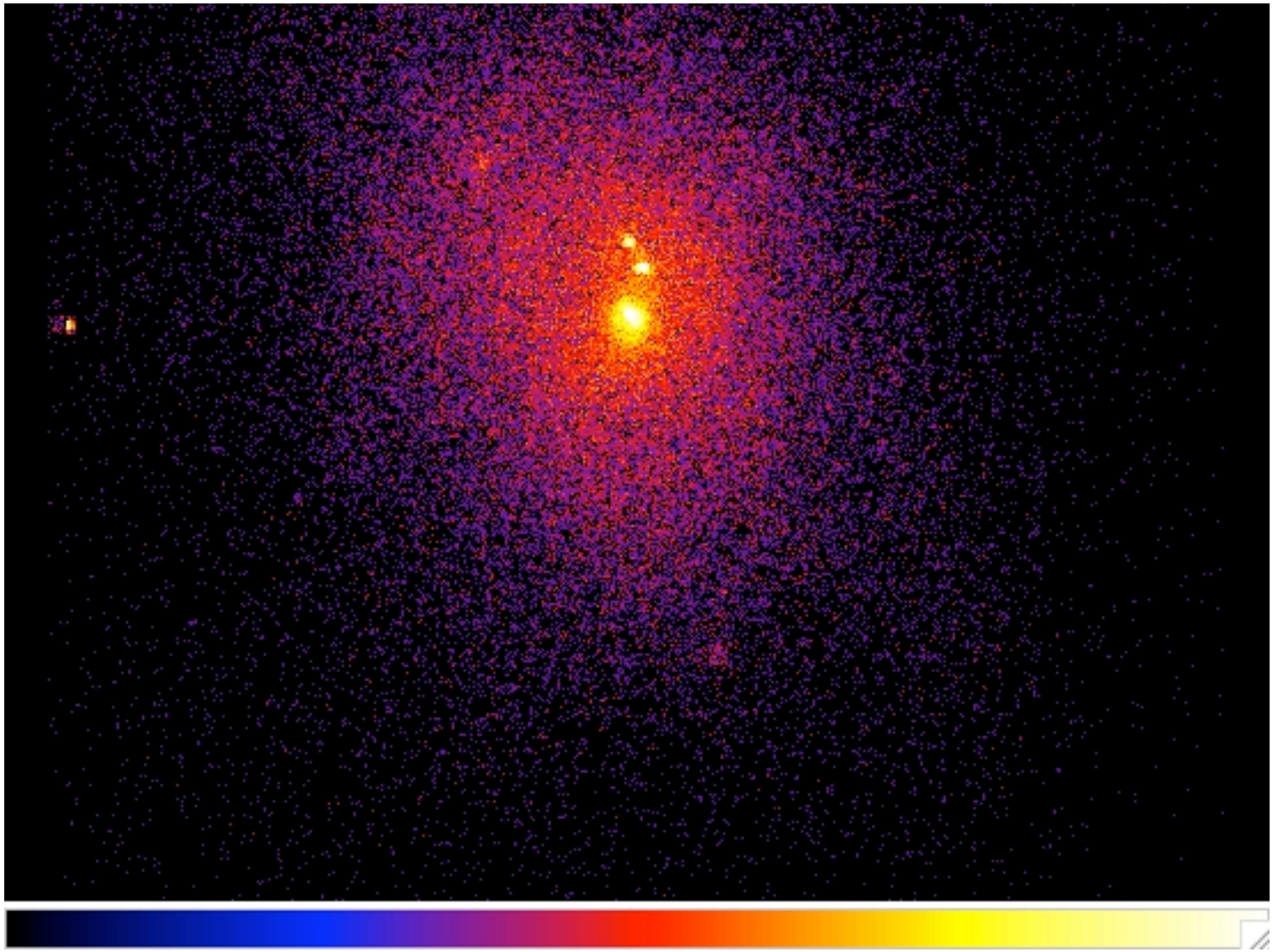

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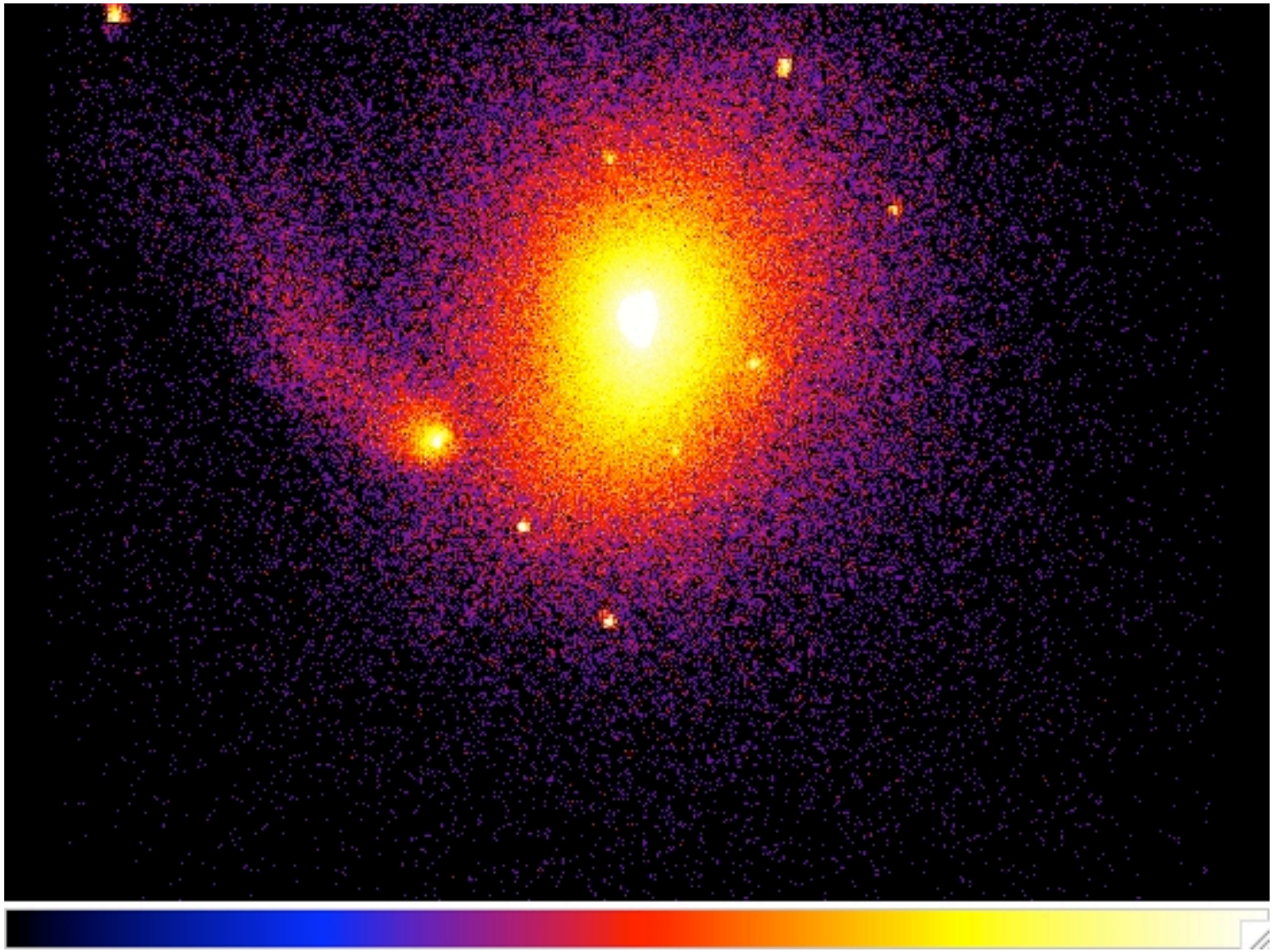
CONCLUSION 2: The X-ray Temperature is good proxy for mass when an accurate masking is done



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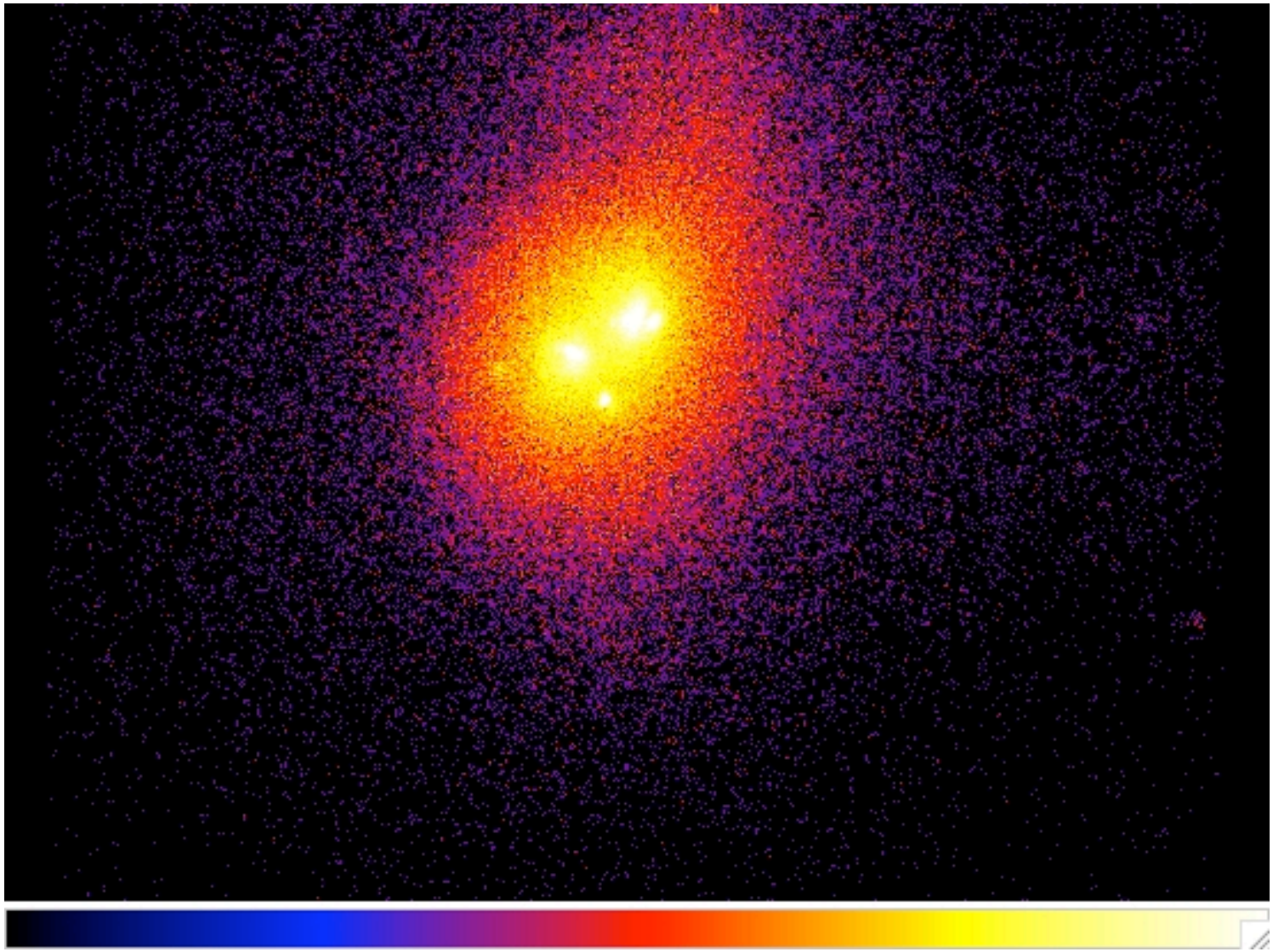

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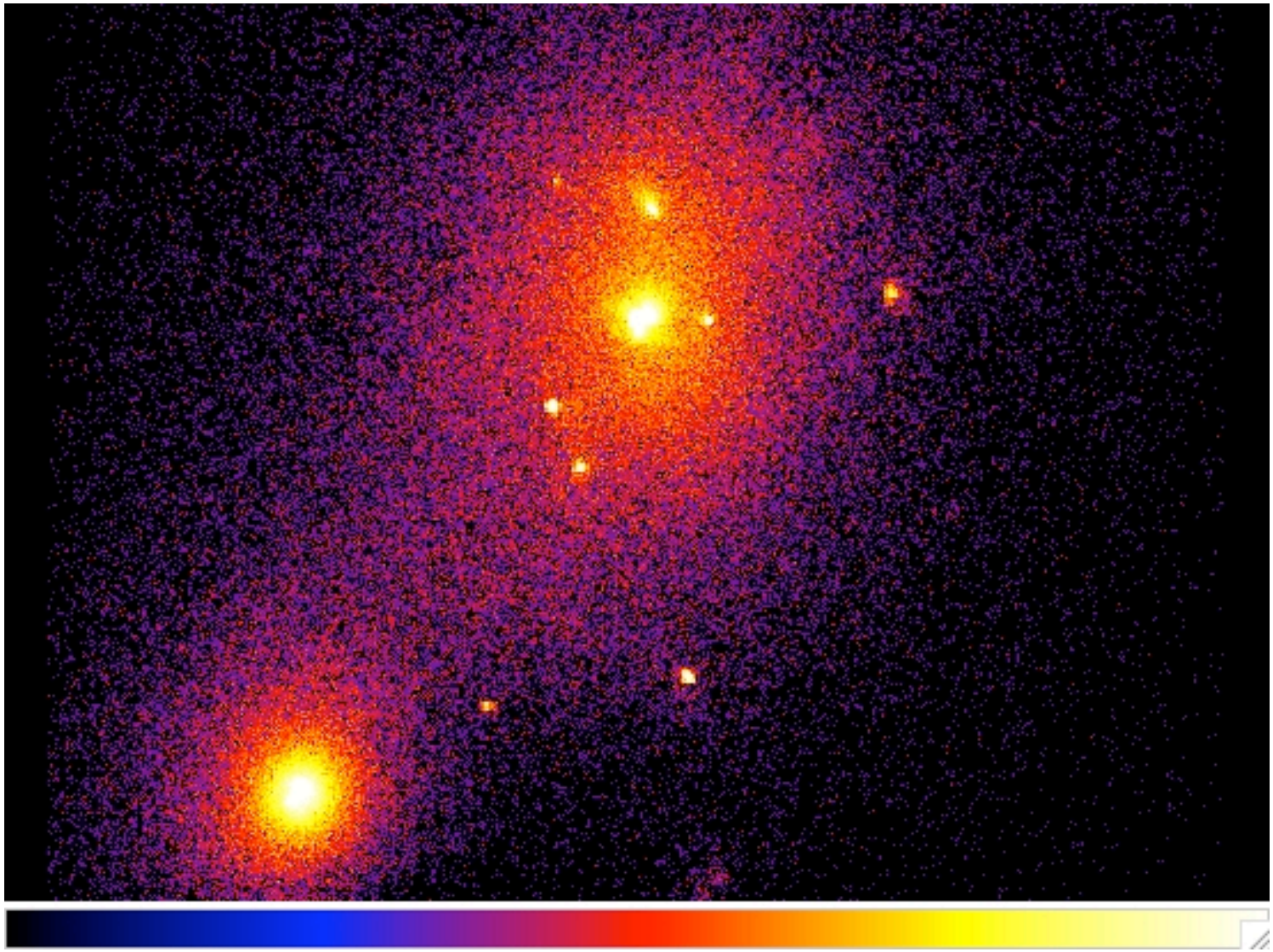

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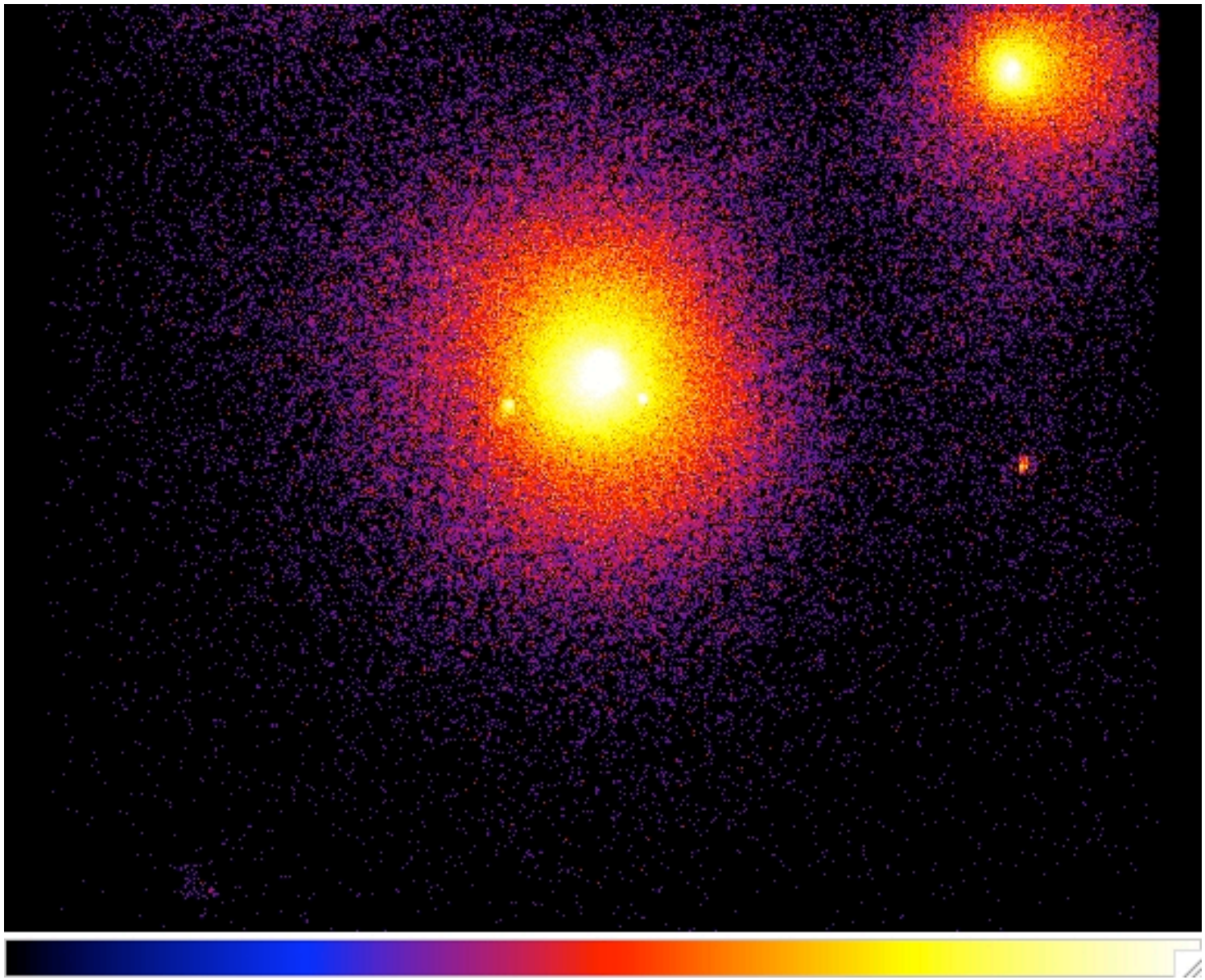
CONCLUSION 3: M_{gas} and Y_X parameter are very robust



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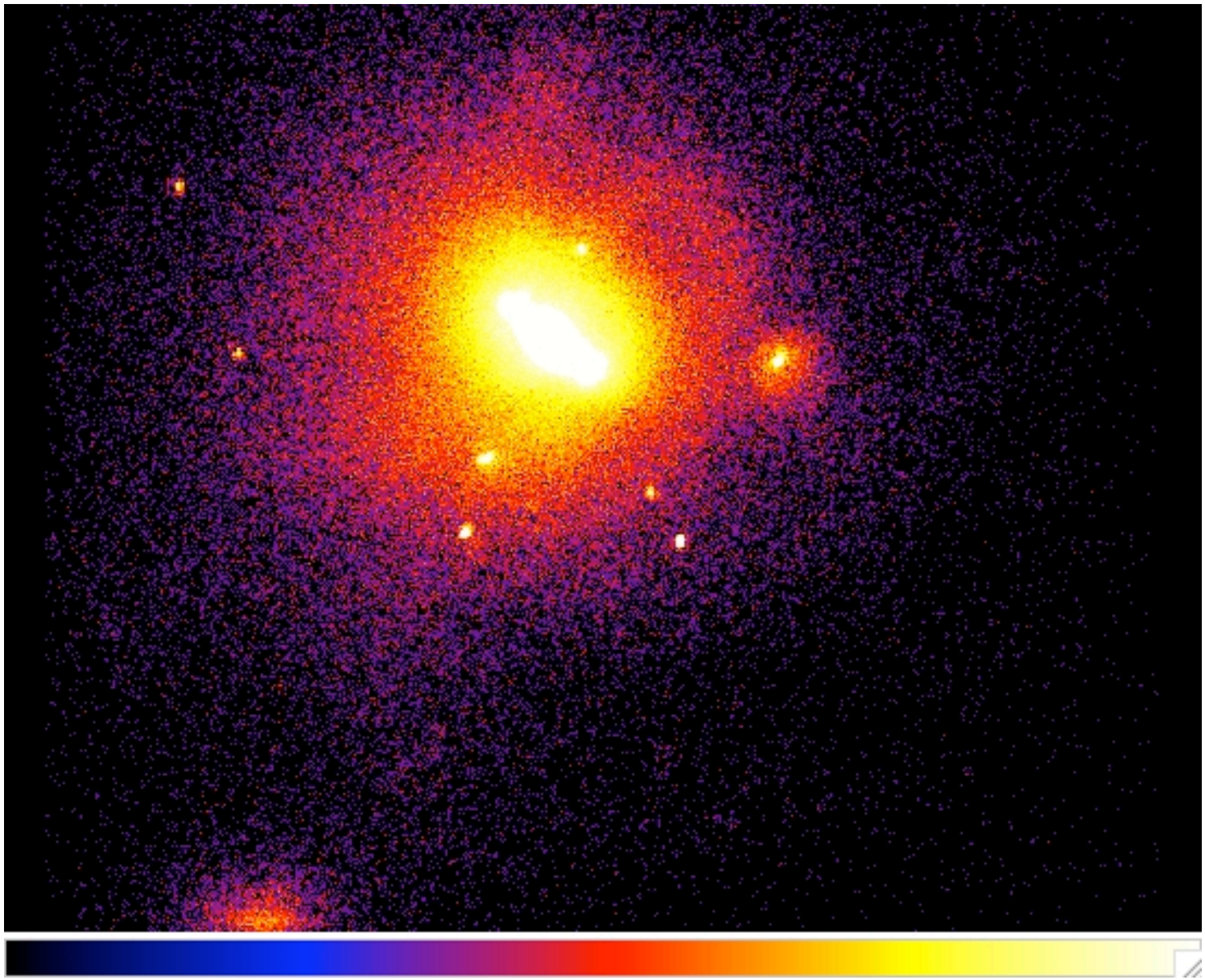

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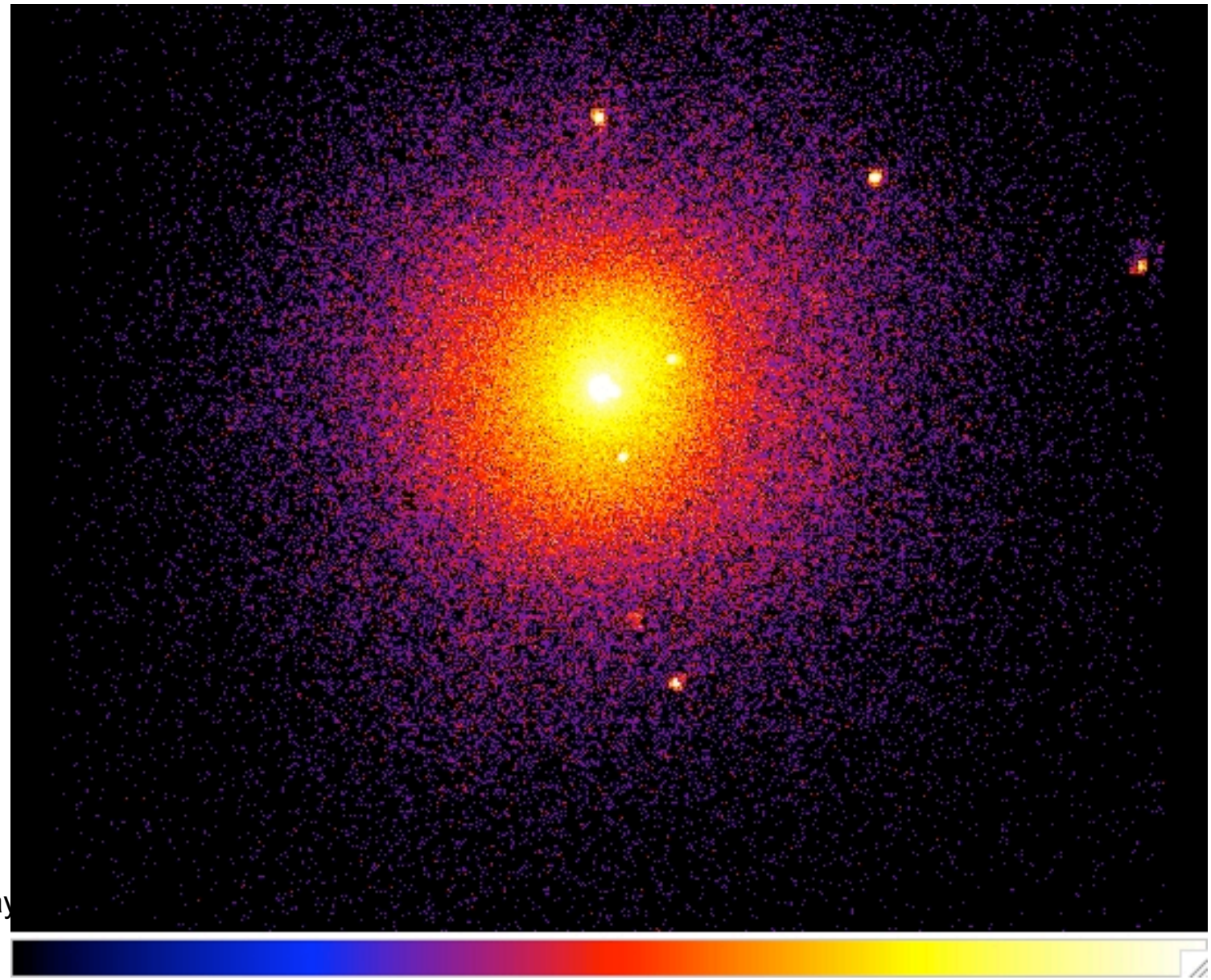

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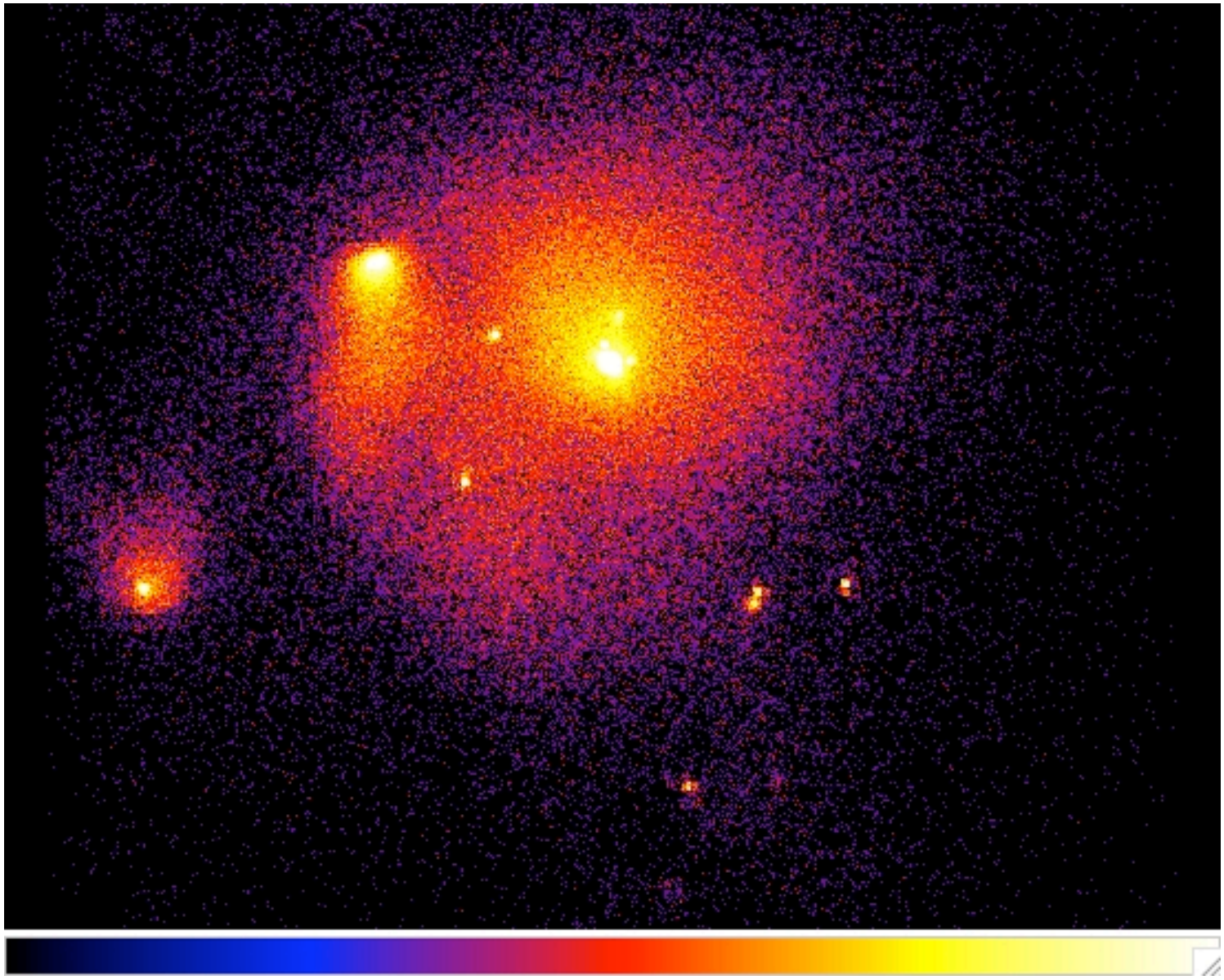
THE PHOTON IMAGES OF150 CLUSTERS FROM BORGANI ET AL. 04 WILL BE SOON PUBBLIC AVAILABLE IN THE ITALIAN VIRTUAL OBSERVATORY (ITVO)



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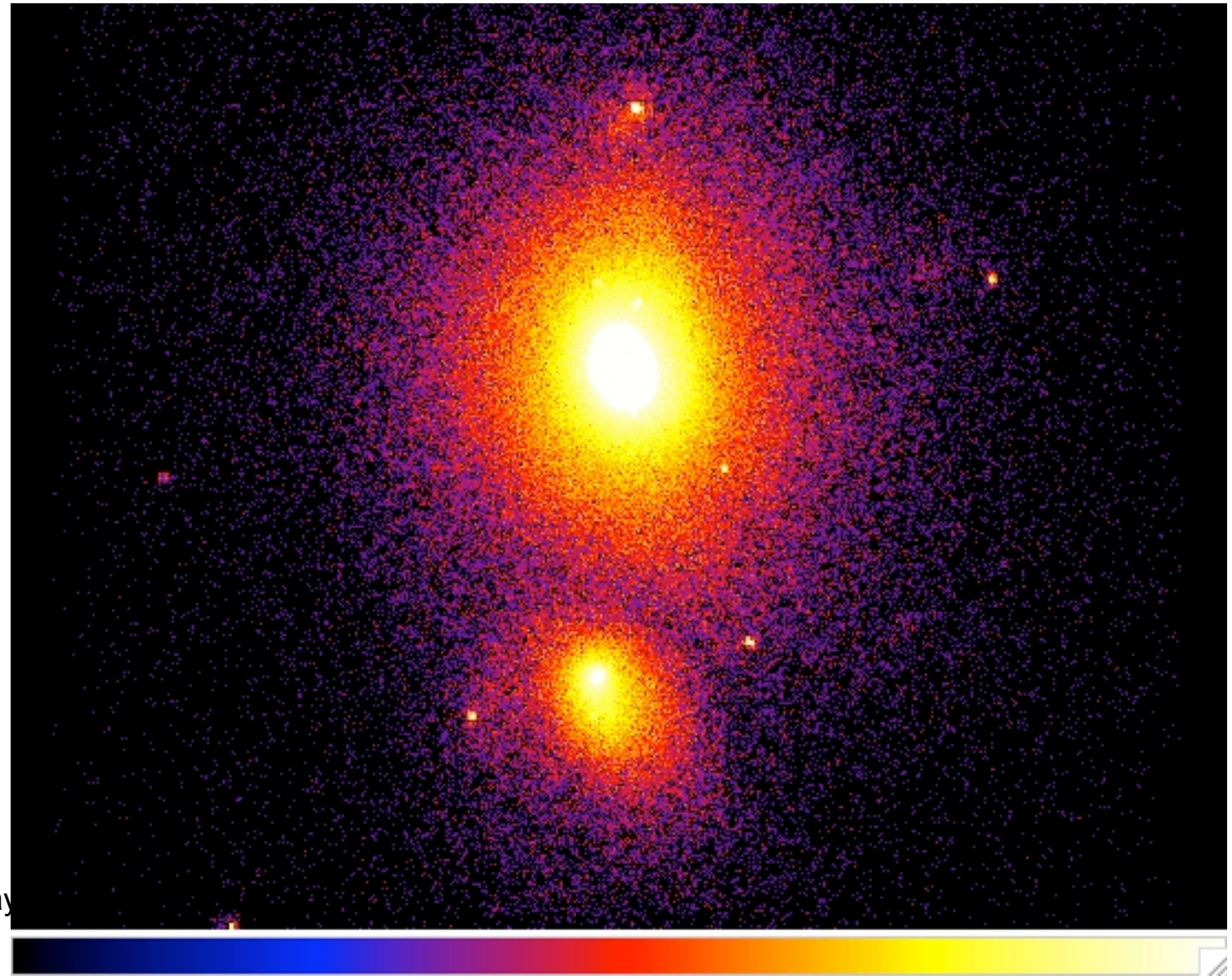

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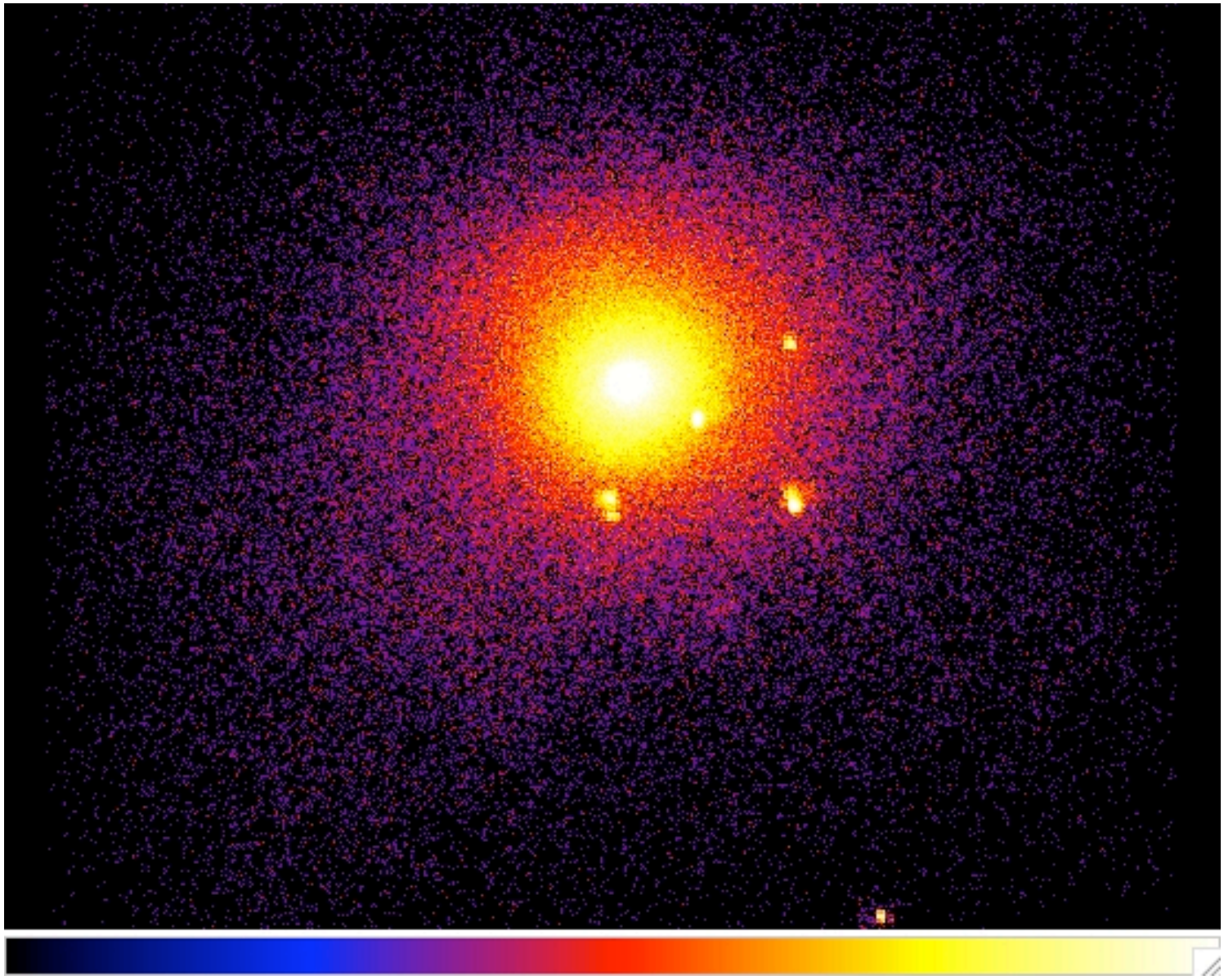

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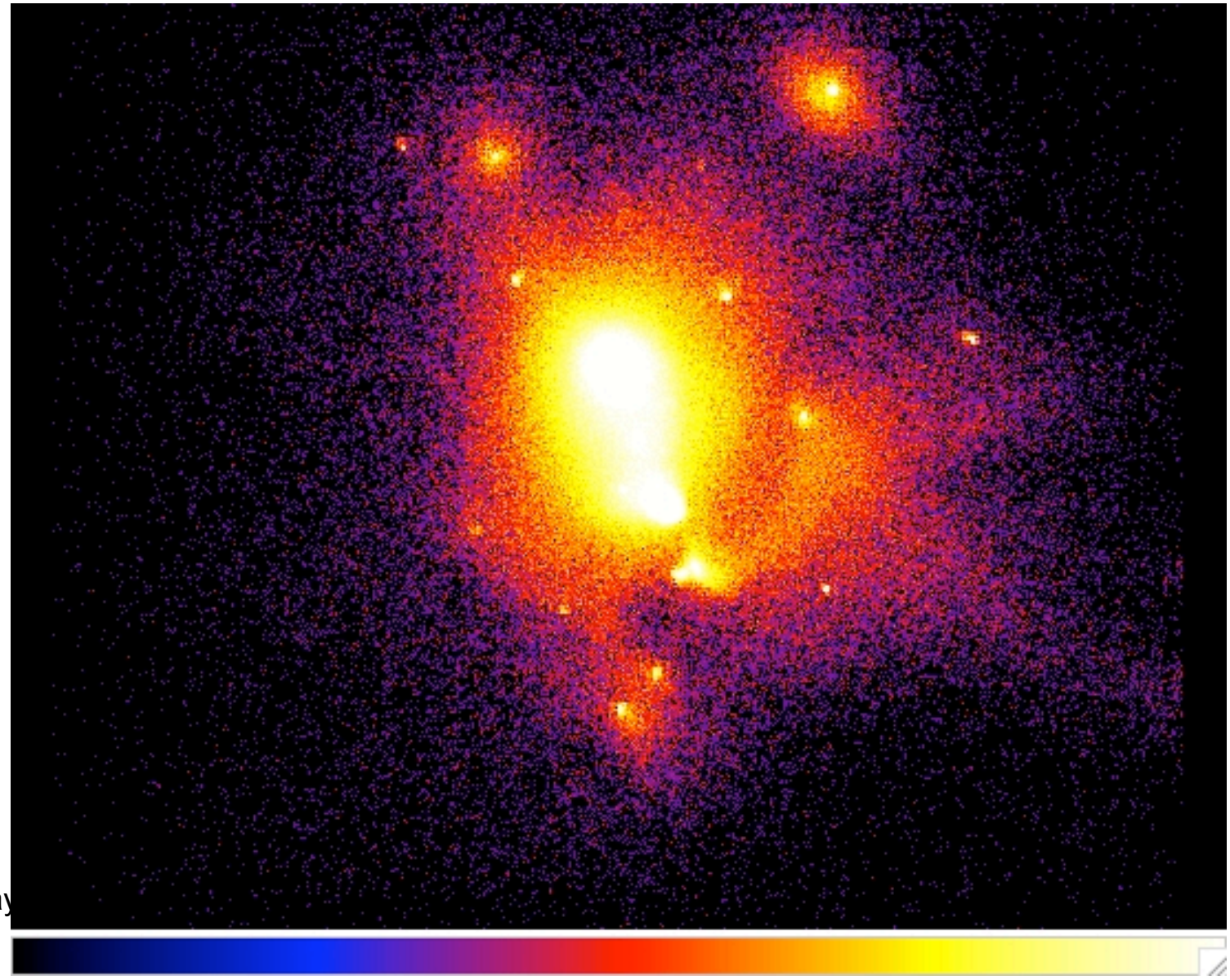

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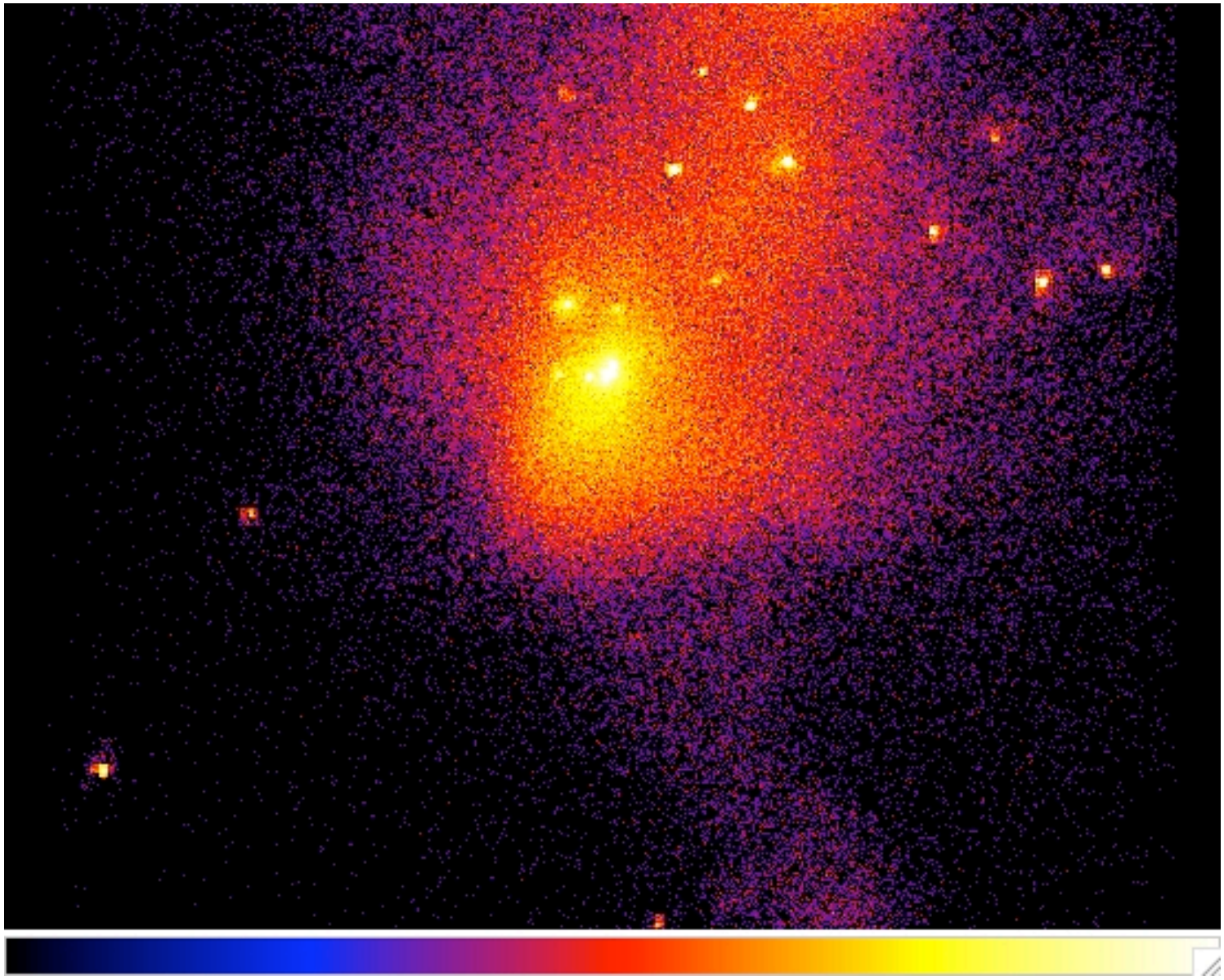

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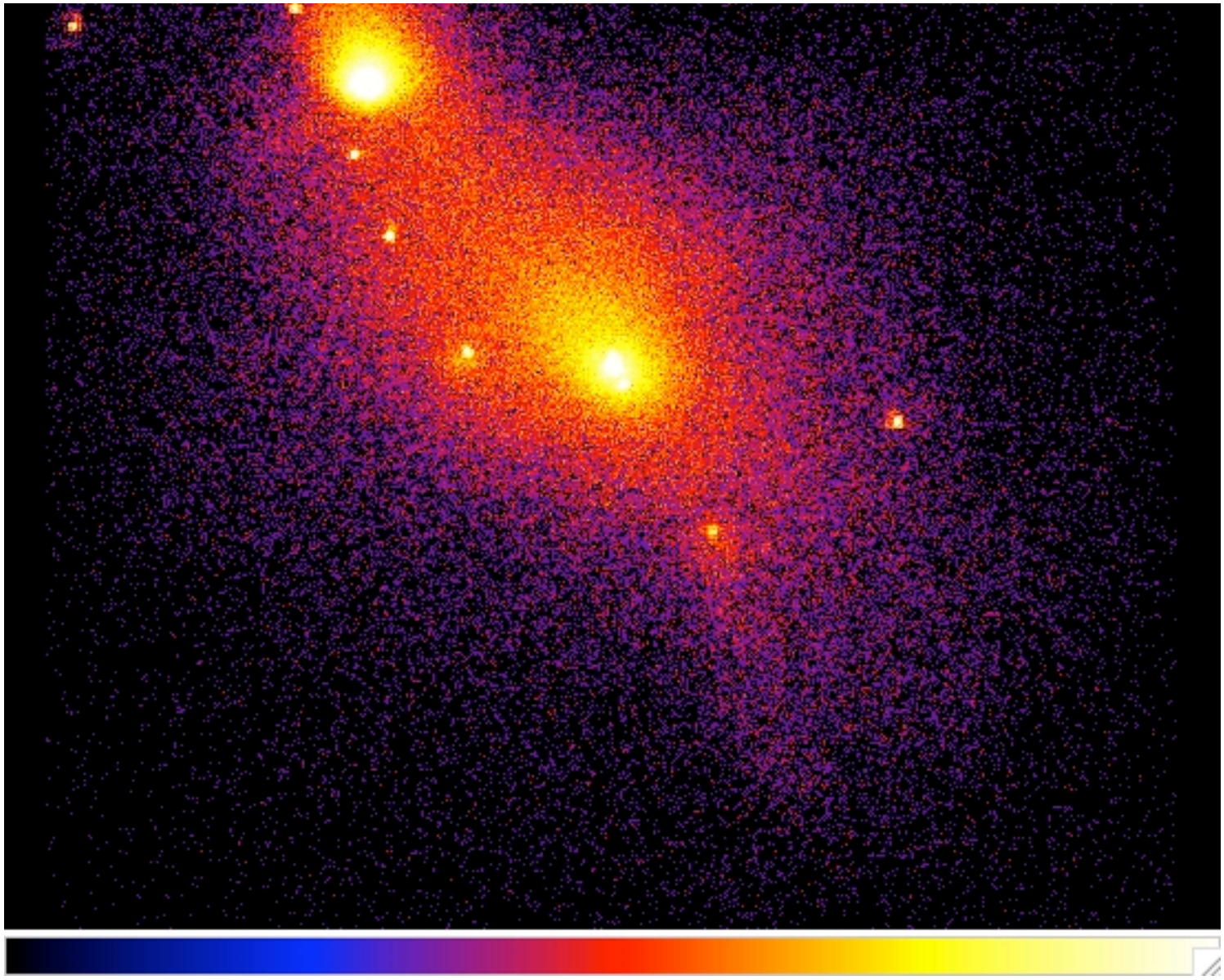

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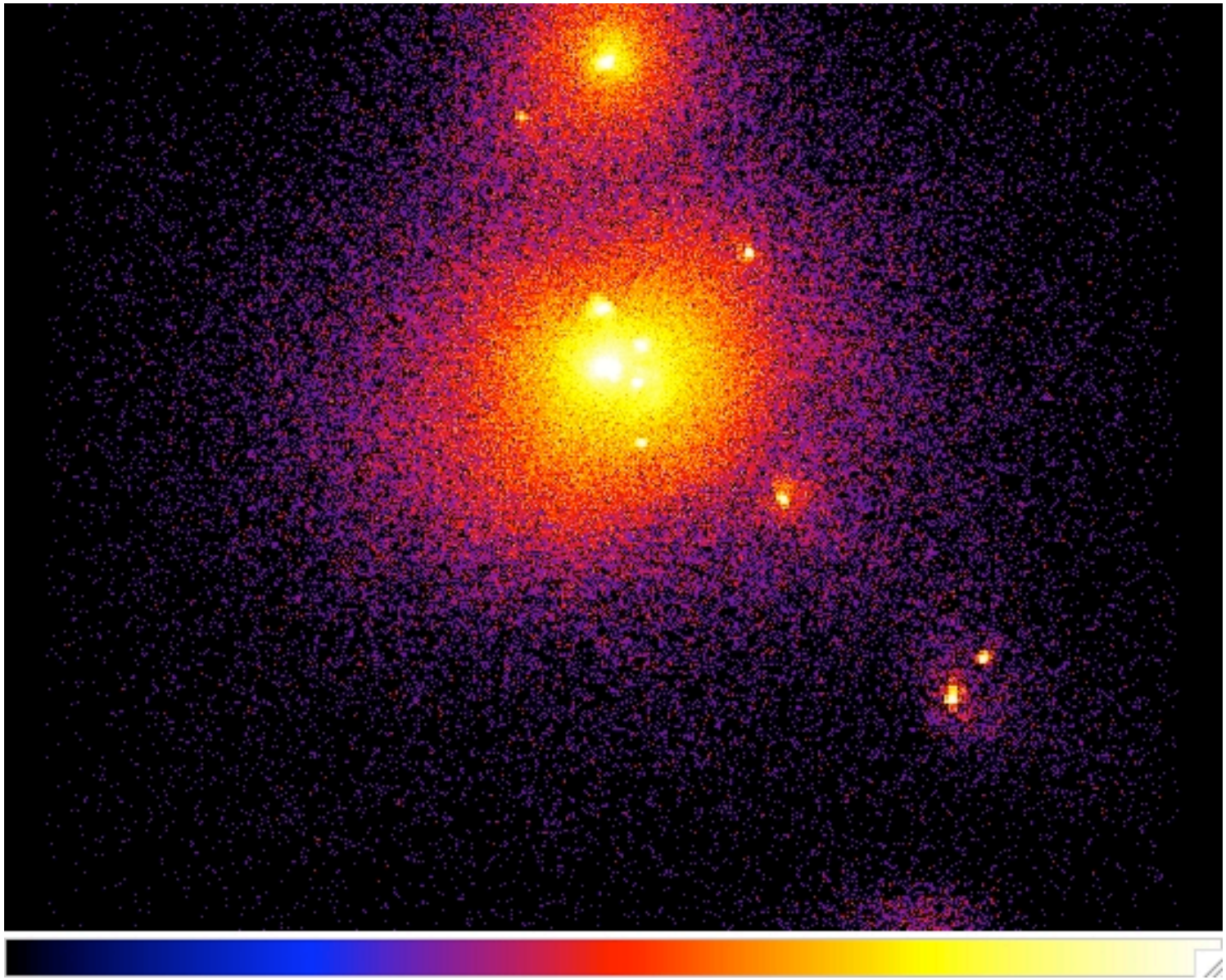

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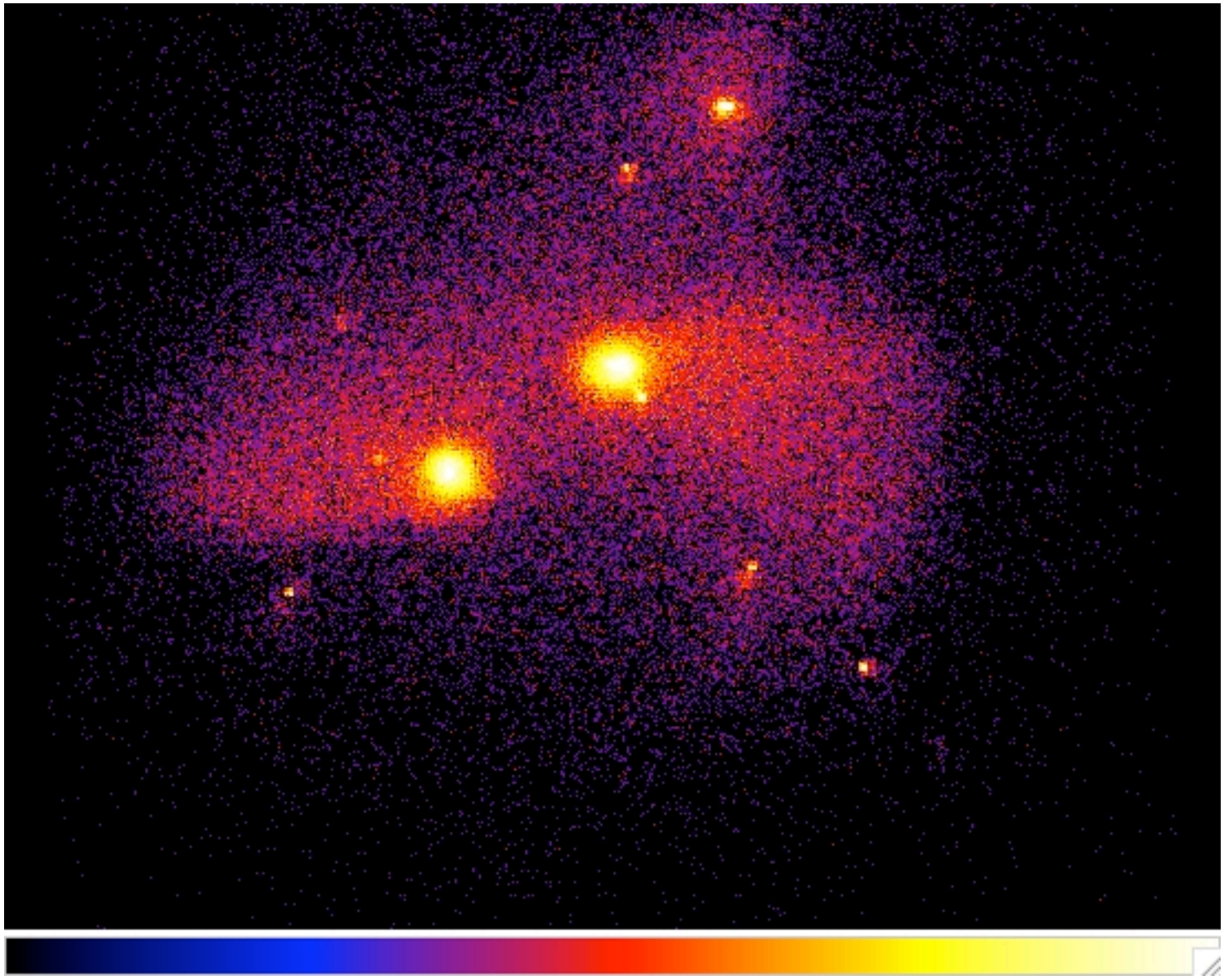

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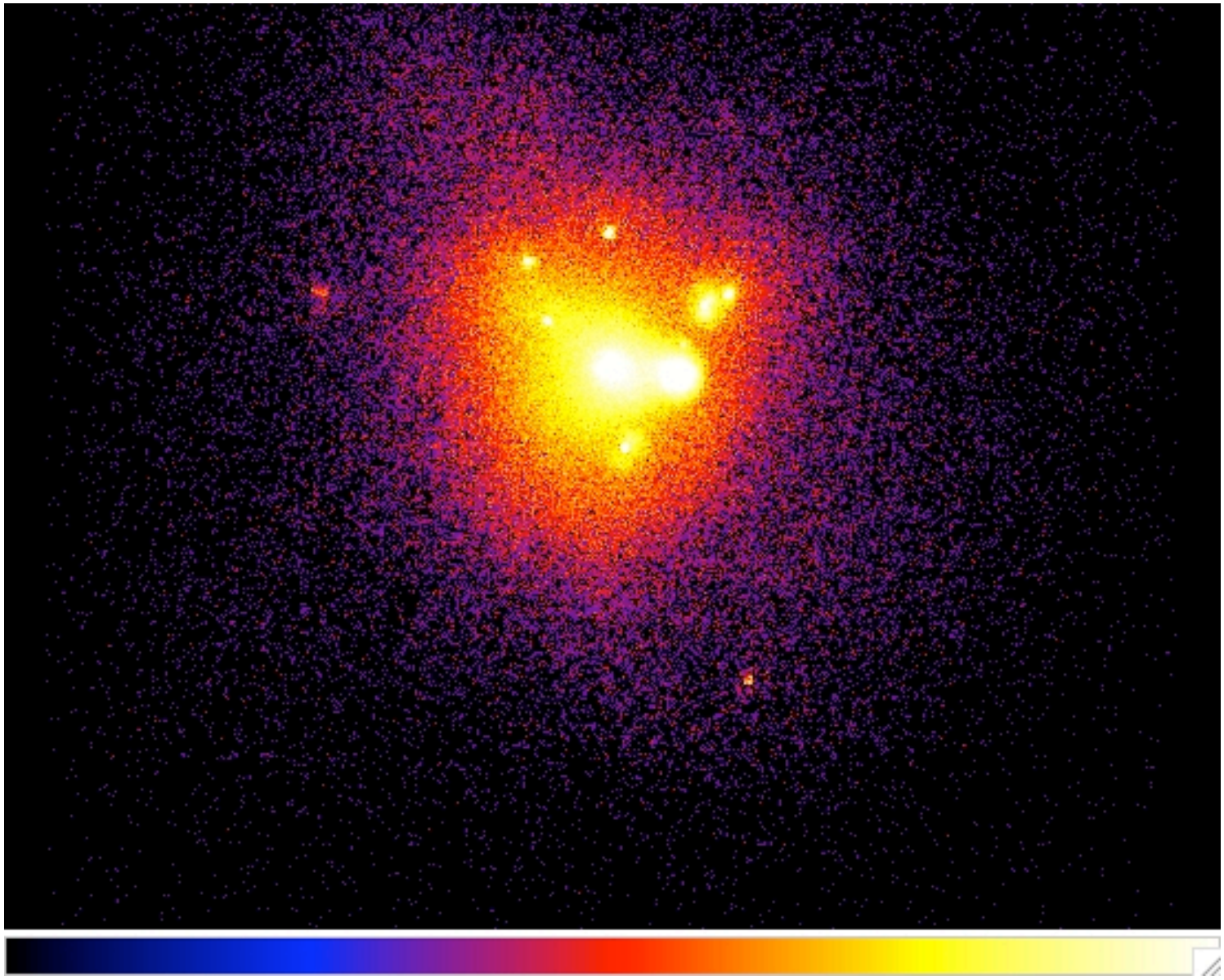

May

M-Yx relation using Borgani et al. 04 clusters.
Cyan points indicate relaxed systems or object with a good spectroscopic determination